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*ON THE DEVELOPMENT OF MATHEMATICAL ANALYSIS AND ITS RELATIONS TO SOME OTHER SCIENCES.**

IT is one of the objects of a congress such as this which now brings us together, to show the bonds between the diverse parts of science taken in its most extended acceptation. So the organizers of this meeting have insisted that the relations between different sections should be put in evidence.

To undertake a study of this sort, somewhat indeterminate in character, it is necessary to forget that all is in all; in what concerns algebra and analysis, a Pythagorean would be dismayed at the extent of his task, remembering the celebrated formula of the school: 'Things are numbers.' From this point of view my subject would be inexhaustible.

But I, for the best of reasons, will make no such pretensions.

In casting merely a glance over the development of our science through the ages, and particularly in the last century, I hope to be able to characterize sufficiently the rôle of mathematical analysis in its relations to certain other sciences.

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I.

It would appear natural to commence by speaking of the concept itself of whole number; but this subject is not alone of logical order, it is also of order historic and psychologic, and would draw us away into too many discussions.

Since the concept of number has been sifted, in it have been found unfathomable depths; thus, it is a question still pending to know, between the two forms, the cardinal number and the ordinal number, under which the idea of number presents itself, which of the two is anterior to the other, that is to say, whether the idea of number properly so called is anterior to that of order, or if it is the inverse.

It seems that the geometer-logician neglects too much in these questions psychology and the lessons uncivilized races give us; it would seem to result from these studies that the priority is with the cardinal number.

It may also be there is no general response to the question, the response varying according to races and according to mentalities.

I have sometimes thought, on this subject, of the distinction between auditives and visuals, auditives favoring the ordinal theory, visuals the cardinal.

But I will not linger on this ground full of snares; I fear that our modern school of logicians with difficulty comes to agreement with the ethnologists and biologists; these latter in questions of origin are always dominated by the evolution idea, and, for more than one of them, logic is only the résumé of ancestral experience. Mathematicians are even reproached with postulating in principle that there is a human mind in some way exterior to things, and that it has its logic. We must, however, submit to this, on pain of constructing nothing. We need this point of departure, and certainly, supposing it to have evolved during the course of prehistoric time, this logic of the human mind was perfectly fixed at the time of the oldest geometric schools, those of Greece; their works appear to have been its first code, as is expressed by the story of Plato writing over the door of his school 'Let no one not a geometer enter here.'

Long before the bizarre word algebra was derived from the Arabic, expressing, it would seem, the operation by which equalities are reduced to a certain canonic form, the Greeks had made algebra without knowing it; relations more intimate could not be imagined than those binding together their algebra and their geometry, or rather, one would be embarrassed to classify, if there were occasion, their geometric algebra, in which they reason not on numbers but on magnitudes.

Among the Greeks also we find a geometric arithmetic, and one of the most interesting phases of its development is the conflict which, among the Pythagoreans, arose in this subject between number and magnitude, apropos of irrationals.

Though the Greeks cultivated the abstract study of numbers, called by them arithmetic, their speculative spirit showed little taste for practical calculation, which they called logistic.

In remote antiquity, the Egyptians and the Chaldeans, and later the Hindus and the Arabs, carried far the science of calculation.

They were led on by practical needs; logistic preceded arithmetic, as land-surveying and geodesy opened the way to geometry; in the same way, trigonometry developed under the influence of the increasing needs of astronomy.

The history of science at its beginnings shows a close relation between pure and applied mathematics; this we will meet again constantly in the course of this study.

We have remained up to this point in the domain which ordinary language calls elementary algebra and arithmetic.

In fact, from the time that the incommensurability of certain magnitudes had been recognized, the infinite had made its appearance, and, from the time of the sophisms of Zeno on the impossibility of motion, the summation of geometric progressions must have been considered.

The procedures of exhaustion which are found in Eudoxus and in Euclid appertain already to the integral calculus, and Archimedes calculates definite integrals.

Mechanics also appeared in his treatise on the quadrature of the parabola, since he first finds the surface of the segment bounded by an arc of a parabola and its chord with the help of the theorem of moments; this is the first example of the relations between mechanics and analysis which since have not ceased developing.

The infinitesimal method of the Greek geometers for the measure of volumes raised questions whose interest is even to-day not exhausted.

In plane geometry, two polygons of the same area are either equivalent or equivalent-by-completion, that is to say, can be decomposed into a finite number of triangles congruent in pairs, or may be regarded as differences of polygons susceptible of such a partition.

It is not the same for the geometry of space, and we have lately learned that stereometry can not, like planimetry, get on without recourse to procedures of exhaustion or of limit, which require the axiom of continuity or the Archimedes assumption.

Without insisting further, this hasty glance at antiquity shows how completely then were amalgamated algebra, arithmetic, geometry and the first endeavors at integral calculus and mechanics, to the point of its being impossible to recall separately their history.

In the middle ages and the renaissance, the geometric algebra of the ancients separated from geometry. Little by little algebra properly so called arrived at independence, with its symbolism and its notation more and more perfected; thus was created this language so admirably clear, which brings about for thought a veritable economy and renders further progress possible.

This is also the moment when distinct divisions are organized.

Trigonometry which, in antiquity, had been only an auxiliary of astronomy is developed independently; toward the same time the logarithm appears, and essential elements are thus put in evidence.

II.

In the seventeenth century, the analytic geometry of Descartes, distinct from what I have just called the geometric algebra of the Greeks by the general and systematic ideas which are at its base, and the new-born dynamic were the origin of the greatest progress of analysis.

When Galileo, starting from the hypothesis that the velocity of heavy bodies in their fall is proportional to the time, from this deduced the law of the distances passed over, to afterward verify it by experiment, he took up again the road upon which Archimedes had formerly entered and on which would follow after him Cavalieri, Fermat and others still, even to Newton and Leibnitz. The integral calculus of the Greek geometers was born again in the kinematic of the great Florentine physicist.

As to the calculus of derivatives or of differentials, it was founded with precision apropos of the drawing of tangents.

In reality, the origin of the notion of derivative is in the confused sense of the mobility of things and of the rapidity more

or less great with which phenomena happen; this is well expressed by the words *fluents* and *fluxions,* which Newton used, and which one might suppose borrowed from old Heraclitus.

The points of view taken by the founders of the science of motion, Galileo, Huygens and Newton, had an enormous influence on the orientation of mathematical analysis.

It was with Galileo an intuition of genius to discover that, in natural phenomena, the determining circumstances of the motion produce accelerations: this must have conducted to the statement of the principle that the rapidity with which the dynamic state of a system changes depends in a determinate manner on its static state alone. In a more general way we reach the postulate that the infinitesimal changes, of whatever nature they may be, occurring in a system of bodies, depend uniquely on the actual state of this system.

In what degree are the exceptions apparent or real? This is a question which was raised only later and which I put aside for the moment.

From the principles enunciated becomes clear a point of capital importance for the analyst: Phenomena are ruled by differential equations which can be formed when observation and experiment have made known for each category of phenomena certain physical laws.

We understand the unlimited hopes conceived from these results. As Bertrand says in the preface of his treatise, 'the early successes were at first such that one might suppose all the difficulties of science surmounted in advance, and believe that the geometers, without being longer distracted by the elaboration of pure mathematics, could turn their meditations exclusively toward the study of the natural laws.'

This was to admit gratuitously that the problems of analysis, to which one was led, would not present very grave difficulties.

Despite the disillusions the future was to bring, this capital point remained, that the problems had taken a precise form, and that a classification could be established in the difficulties to be surmounted.

There was, therefore, an immense advance, one of the greatest ever made by the human mind. We understand also why the theory of differential equations acquired a considerable importance.

I have anticipated somewhat, in presenting things under a form so analytic. Geometry was intermingled in all this progress. Huygens, for example, followed always by preference the ancients, and his 'Horologium oscillatorium' rests at the same time on infinitesimal geometry and mechanics; in the same way, in the 'Principia' of Newton, the methods followed are synthetic.

It is above all with Leibnitz that science takes the paths which were to lead to what we call mathematical analysis; it is he who, for the first time, in the latter years of the seventeenth century, pronounces the word function.

By his systematic spirit, by the numerous problems he treated, even as his disciples James and John Bernoulli, he established in a final way the power of the doctrines to the edification of which had successively contributed a long series of thinkers from the distant times of Eudoxus and of Archimedes.

The eighteenth century showed the extreme fecundity of the new methods. That was a strange time, the era of mathematical duels where geometers hurled defiance, combats not always without acrimony, when Leibnitzians and Newtonians encountered in the lists.

From the purely analytic point of view, the classification and study of simple functions is particularly interesting; the func-

tion idea, on which analysis rests, is thus developed little by little.

The celebrated works of Euler hold then a considerable place. However, the numerous problems which present themselves to the mathematicians leave no time for a scrutiny of principles; the foundations themselves of the doctrine are elucidated slowly, and the *mot* attributed to d'Alembert 'allez en avant et la foi vous viendra' is very characteristic of this epoch.

Of all the problems started at the end of the seventeenth century or during the first half of the eighteenth, it will suffice for me to recall those isoperimetric problems which gave birth to the calculus of variations.

I prefer to insist on the interpenetration still more intimate between analysis and mechanics when, after the inductive period of the first age of dynamics, the deductive period was reached where one strove to give a final form to the principles. The mathematical and formal development played then the essential rôle, and the analytic language was indispensable to the greatest extension of these principles.

There are moments in the history of the sciences and, perhaps, of society, when the spirit is sustained and carried forward by the words and the symbols it has created, and when generalizations present themselves with the least effort. Such was particularly the rôle of analysis in the formal development of mechanics.

Allow me a remark just here. It is often said an equation contains only what one has put in it. It is easy to answer, first, that the new form under which one finds the things constitutes often of itself an important discovery.

But sometimes there is more; analysis, by the simple play of its symbols, may suggest generalizations far surpassing the primitive outline. Is it not so with the principle of virtual velocities, of which the first idea comes from the simplest mechanisms; the analytic form which translates it will suggest extensions leading far from the point of departure.

In the same sense, it is not just to say analysis has created nothing, since these more general conceptions are its work. Still another example is furnished us by Lagrange's system of equations; here calculus transformations have given the type of differential equations to which one tends to carry back to-day the notion of mechanical explanation.

There are in science few examples comparable to this, of the importance of the form of an analytic relation and of the power of generalization of which it may be capable.

It is very clear that, in each case, the generalizations suggested should be made precise by an appeal to observation and experiment, then it is still the calculus which searches out distant consequences for checks, but this is an order of ideas which I need not broach here.

Under the impulse of the problems set by geometry, mechanics and physics, we see develop or take birth almost all the great divisions of analysis. First were met equations with a single independent variable. Soon appear partial differential equations, with vibrating cords, the mechanics of fluids and the infinitesimal geometry of surfaces.

This was a wholly new analytic world; the origin itself of the problems treated was an aid which from the first steps permits no wandering, and in the hands of Monge geometry rendered useful services to the new-born theories.

But of all the applications of analysis, none had then more renown than the problems of celestial mechanics set by the knowledge of the law of gravitation and to which the greatest geometers gave their names.

Theory never had a more beautiful triumph; perhaps one might add that it was too complete, because it was at this moment above all that were conceived for natural philosophy the hopes at least premature of which I spoke above.

In all this period, especially in the second half of the eighteenth century, what strikes us with admiration and is also somewhat confusing, is the extreme importance of the applications realized, while the pure theory appeared still so ill assured. One perceives it when certain questions are raised like the degree of arbitrariness in the integral of vibrating cords, which gives place to an interminable and inconclusive discussion.

Lagrange appreciated these insufficiencies when he published his theory of analytic functions where he strove to give a precise foundation to analysis.

One can not too much admire the marvelous presentiment he had of the rôle which were to play the functions we call, with him, analytic; but we may confess that we stand astonished before the demonstration he believed to have given of the possibilty of the development of a function in Taylor's series.

The exigencies in questions of pure analysis were less at this epoch. Confiding in intuition, one was content with certain probabilities and agreed implicitly about certain hypotheses that it seemed useless to formulate in an explicit way; in reality, one had confidence in the ideas which so many times had shown themselves fecund, which is very nearly the *mot* of d'Alembert.

The demand for rigor in mathematics has had its successive approximations, and in this regard our sciences have not the absolute character so many people attribute to them.

III.

We have now reached the first years of the nineteenth century. As we have explained, the great majority of the analytic researches had, in the eighteenth century, for occasion a problem of geometry, and especially of mechanics and of physics, and we have scarcely found the logical and esthetic preoccupations which are to give a physiognomy so different to so many mathematical works, above all in the latter two thirds of the nineteenth century.

Not to anticipate, however, after so many examples of the influences of physics on the developments of analysis, we meet still a new one, and one of the most memorable, in Fourier's theory of heat. He commences by forming the partial differential equations which govern temperature.

What are for a partial differential equation the conditions at the limits permitting the determination of a solution?

For Fourier, the conditions are suggested by the physical problem and the methods that he followed have served as models to the physicist-geometers of the first half of the last century.

One of these consists in forming a series with certain simple solutions. Fourier thus obtained the first types of developments more general than the trigonometric developments, as in the problem of the cooling of a sphere, where he applies his theory to the terrestrial globe, and investigates the law which governs the variations of temperature in the ground, trying to go even as far as numerical applications.

In the face of so many beautiful results, we understand the enthusiasm of Fourier which scintillates from every line of his preliminary discourse. Speaking of mathematical analysis, he says, "there could not be a language more universal, more simple, more exempt from errors and from obscurities, that is to say, more worthy to express

the invariable relations of natural things. Considered under this point of view, it is as extended as nature herself; it defines all sensible relations, measures times, spaces, forces, temperatures. This difficult science forms slowly, but it retains all the principles once acquired. It grows and strengthens without cease in the midst of so many errors of the human mind.''

The elegy is magnificent, but permeating it we see the tendency which makes all analysis uniquely an auxiliary, however incomparable, of the natural sciences, a tendency, in conformity, as we have seen, with the development of science during the preceding two centuries; but we reach just here an epoch where new tendencies appear.

Poisson having in a report on the Fundamenta recalled the reproach made by Fourier to Abel and Jacobi of not having occupied themselves preferably with the movement of heat, Jacobi wrote to Legendre: 'It is true that Monsieur Fourier held the view that the principal aim of mathematics was public utility, and the explanation of natural phenomena; but a philosopher such as he should have known that the unique aim of science is the honor of the human spirit, and that from this point of view, a question about numbers is as important as a question about the system of the world.' This was without doubt also the opinion of the grand geometer of Goettingen, who called mathematics the queen of the sciences, and arithmetic the queen of mathematics.

It would be ridiculous to oppose one to the other these two tendencies; the harmony of our science is in their synthesis.

The time was about to arrive when one would feel the need of inspecting the foundations of the edifice, and of making the inventory of accumulated wealth, using more of the critical spirit. Mathematical thought was about to gather more force by retiring into itself; the problems were exhausted for a time, and it is not well for all seekers to stay on the same road. Moreover, difficulties and paradoxes remaining unexplained made necessary the progress of pure theory.

The path on which this should move was traced in its large outlines, and there it could move with independence without necessarily losing contact with the problems set by geometry, mechanics and physics.

At the same time more interest was to attach to the philosophic and artistic side of mathematics, confiding in a sort of preestablished harmony between our logical and esthetic satisfactions and the necessities of future applications.

Let us recall rapidly certain points in the history of the revision of principles where Gauss, Cauchy and Abel likewise were laborers of the first hour. Precise definitions of continuous functions, and their most immediate properties, simple rules on the convergence of series, were formulated; and soon was established under very general conditions, the possibility of trigonometric developments, legitimatizing thus the boldness of Fourier.

Certain geometric intuitions relative to areas and to arcs give place to rigorous demonstration. The geometers of the eighteenth century had necessarily sought to give account of the degree of the generality of the solution of ordinary differential equations. Their likeness to equations of finite differences led easily to the result; but the demonstration so conducted must not be pressed very close.

Lagrange, in his lessons on the calculus of functions had introduced greater precision, and starting from Taylor's series, he saw that the equation of order m leaves indeterminate the function, and its $m-1$ first derivatives for the initial value of the variable; we are not surprised that La-

grange did not set himself the question of convergence.

In twenty or thirty years the exigencies in the rigor of proofs had grown. One knew that the two preceding modes of demonstration are susceptible of all the precision necessary.

For the first, there was need of no new principle; for the second it was necessary that the theory should develop in a new way. Up to this point, the functions and the variables had remained real. The consideration of complex variables comes to extend the field of analysis. The functions of a complex variable with unique derivative are necessarily developable in Taylor's series; we come back thus to the mode of development of which the author of the theory of analytic functions had understood the interest, but of which the importance could not be put fully in evidence in limiting oneself to real variables. They also owe the grand rôle that they have not ceased to play to the facility with which we can manage them, and to their convenience in calculation.

The general theorems of the theory of analytic functions permitted to reply with precision to questions remaining up to that time undecided, such as the degree of generality of the integrals of differential equations. It became possible to push even to the end the demonstration sketched by Lagrange for an ordinary differential equation. For a partial differential equation or a system of such equations, precise theorems were established. It is not that on this latter point the results obtained, however important they may be, resolve completely the diverse questions that may be set; because in mathematical physics, and often in geometry, the conditions at the limits are susceptible of forms so varied that the problem called Cauchy's appears often under very severe form. I will shortly return to this capital point.

IV.

Without restricting ourselves to the historic order, we will follow the development of mathematical physics during the last century, in so far as it interests analysis.

The problems of calorific equilibrium lead to the equation already encountered by Laplace in the study of attraction. Few equations have been the object of so many works as this celebrated equation. The conditions at the limits may be of divers forms. The simplest case is that of the calorific equilibrium of a body of which we maintain the elements of the surface at given temperatures; from the physical point of view, it may be regarded as evident that the temperature, continuous within the interior since no source of heat is there, is determined when it is given at the surface.

A more general case is that where, the state remaining permanent, there might be radiation toward the outside with an emissive power varying on the surface in accordance with a given law; in particular the temperature may be given on one portion, while there is radiation on another portion.

These questions, which are not yet resolved in their greatest generality, have greatly contributed to the orientation of the theory of partial differential equations. They have called attention to types of determinations of integrals, which would not have presented themselves in remaining at a point of view purely abstract.

Laplace's equation had been met already in hydrodynamics and in the study of attraction inversely as the square of the distance. This latter theory has led to putting in evidence the most essential elements such as the potentials of simple strata and of double strata. Analytic combinations of the highest importance were there met, which since have been notably generalized, such as Green's formula.

The fundamental problems of static electricity belong to the same order of ideas, and that was surely a beautiful triumph for theory, the discovery of the celebrated theorem on electric phenomena in the interior of hollow conductors, which later Faraday rediscovered experimentally, without having known of Green's memoir.

All this magnificent ensemble has remained the type of the theories already old of mathematical physics, which seem to us almost to have attained perfection, and which exercise still so happy an influence on the progress of pure analysis in suggesting to it the most beautiful problems. The theory of functions offers us another memorable affiliation.

There the analytic transformations which come into play are not distinct from those we have met in the permanent movement of heat. Certain fundamental problems of the theory of functions of a complex variable lost then their abstract enunciation to take a physical form, such as that of the distribution of temperature on a closed surface of any connection and not radiating, in calorific equilibrium with two sources of heat which necessarily correspond to flows equal and of contrary signs. Transposing, we face a question relative to Abelian integrals of the third species in the theory of algebraic curves.

The examples which precede, where we have envisaged only the equations of heat and of attraction, show that the influence of physical theories has not been exercised only on the general nature of the problems to be solved, but even in the details of the analytic transformations. Thus is currently designated in recent memoirs on partial differential equations under the name of Green's formula, a formula inspired by the primitive formula of the English physicist. The theory of dynamic electricity and that of magnetism, with Ampère and Gauss, have been the origin of important progress; the study of curvilinear integrals and that of the integrals of surfaces have taken thence all their developments, and formulas, such as that of Stokes which might also be called Ampère's formula, have appeared for the first time in memoirs on physics. The equations of the propagation of electricity, to which are attached the names of Ohm and Kirchoff, while presenting a great analogy with those of heat, offer often conditions at the limits a little different; we know all that telegraphy by cables owes to the profound discussion of a Fourier's equation carried over into electricity.

The equations long ago written of hydrodynamics, the equations of the theory of electricity, those of Maxwell and of Hertz in electromagnetism have offered problems analogous to those recalled above, but under conditions still more varied. Many unsurmounted difficulties are there met with; but how many beautiful results we owe to the study of particular cases, whose number one would wish to see increase. To be noted also as interesting at once to analysis and physics are the profound differences which the propagation may present according to the phenomena studied. With equations such as those of sound, we have propagation by waves; with the equation of heat, each variation is felt instantly at every distance, but very little at a very great distance, and we can not then speak of velocity of propagation.

In other cases of which Kirchoff's equation relative to the propagation of electricity with induction and capacity offers the simplest type, there is a wave front with a velocity determined but with a remainder behind which does not vanish.

These diverse circumstances reveal very different properties of integrals; their study has been delved into only in a few particular cases, and it raises questions

into which enter the most profound notions of modern analysis.

V.

I will enter into certain analytic details especially interesting for mathematical physics.

The question of the generality of the solution of a partial differential equation has presented some apparent paradoxes. For the same equation, the number of arbitrary functions figuring in the general integral was not always the same, following the form of the integral envisaged. Thus Fourier, studying the equation of heat in an indefinite medium, considers as evident that a solution will be determined if its value for $t=0$ is given, that is to say one arbitrary function of the three coordinates x, y, z; from the point of view of Cauchy, we may consider, on the contrary, that in the general solution there are two arbitrary functions of the three variables. In reality, the question, as it has long been stated, has not a precise signification.

In the first place, when it is a question only of analytic functions, any finite number of functions of any number of independent variables presents, from the arithmetical point of view, no greater generality than a single function of a single variable, since in the one case and in the other the ensemble of coefficients of the development forms an enumerable series. But there is something more. In reality, beyond the conditions which are translated by given functions, an integral is subjected to conditions of continuity, or is to become infinite in a determined manner for certain elements; one may so be led to regard as equivalent to an arbitrary function the condition of continuity in a given space, and then we clearly see how badly formulated is the question of giving the number of the arbitrary functions. It is at times a delicate matter to demonstrate that conditions determine in a unique manner a solution, when we do not wish to be contented with probabilities; it is then necessary to make precise the manner in which the function and certain of its derivatives conduct themselves.

Thus in Fourier's problem relative to an indefinite medium certain hypotheses must be made about the function and its first derivatives at infinity, if we wish to establish that the solution is unique.

Formulas analogous to Green's render great services, but the demonstrations one deduces from them are not always entirely rigorous, implicitly supposing fulfilled for the limits conditions which are not, *a priori* at least, necessary. This is, after so many others, a new example of the evolution of exigencies in the rigor of proofs.

We remark, moreover, that the new study, rendered necessary, has often led to a better account of the nature of integrals.

True rigor is fecund, thus distinguishing itself from another purely formal and tedious, which spreads a shadow over the problems it touches.

The difficulties in the demonstration of the unity of a solution may be very different according as it is question of equations of which all the integrals are or are not analytic. This is an important point, and shows that even when we wish to put them aside, it is necessary sometimes to consider non-analytic functions.

Thus we can not affirm that Cauchy's problem determines in a unique manner one solution, the data of the problem being general, that is to say not being characteristic.

This is surely the case, if we envisage only analytic integrals, but with non-analytic integrals, there may be contacts of order infinite. And theory here does not outstrip applications; on the contrary, as the following example shows:

Does the celebrated theorem of Lagrange

on the potentials of velocity in a perfect fluid hold good in a viscid fluid? Examples have been given where the coordinates of different points of a viscous fluid starting from rest are not expressible as analytic functions of the time starting from the initial instant of the motion, and where the nul rotations as well as all their derivatives with respect to the time at this instant are, however, not identically nul; Lagrange's theorem, therefore, does not hold true.

These considerations sufficiently show the interest it may have to be assured that all the integrals of a system of partial differential equations continuous as well as all their derivatives up to a determined order in a certain field of real variables are analytic functions; it is understood, we suppose, there are in the equations only analytic elements. We have for linear equations precise theorems, all the integrals being analytic, if the characteristics are imaginary, and very general propositions have also been obtained in other cases.

The conditions at the limits that one is led to assume are very different according as it is question of an equation of which the integrals are or are not analytic. A type of the first case is given by the problem generalized by Dirichlet; conditions of continuity there play an essential part, and, in general, the solution can not be prolonged from the two sides of the continuum which serves as support to the data; it is no longer the same in the second case, where the disposition of this support in relation to the characteristics plays the principal rôle, and where the field of existence of the solution presents itself under wholly different conditions.

All these notions, difficult to make precise in ordinary language and fundamental for mathematical physics, are not of less interest for infinitesimal geometry.

It will suffice to recall that all the surfaces of constant positive curvature are analytic, while there exist surfaces of constant negative curvature not analytic.

From antiquity has been felt the confused sentiment of a certain economy in natural phenomena; one of the first precise examples is furnished by Fermat's principle relative to the economy of time in the transmission of light.

Then we came to recognize that the general equations of mechanics correspond to a problem of minimum, or more exactly of variation, and thus we obtained the principle of virtual velocities, then Hamilton's principle, and that of least action. A great number of problems appeared then as corresponding to minima of certain definite integrals.

This was a very important advance, because the existence of a minimum could in many cases be regarded as evident, and consequently the demonstration of the existence of the solution was effected.

This reasoning has rendered immense services; the greatest geometers, Gauss in the problem of the distribution of an attracting mass corresponding to a given potential, Riemann in his theory of Abelian functions, have been satisfied with it. To-day our attention has been called to the dangers of this sort of demonstration; it is possible for the minima to be simply limits and not to be actually attained by veritable functions possessing the necessary properties of continuity. We are, therefore, no longer content with the probabilities offered by the reasoning long classic.

Whether we proceed indirectly or whether we seek to give a rigorous proof of the existence of a function corresponding to the minimum, the route is long and arduous.

Further, not the less will it be always useful to connect a question of mechanics or of mathematical physics with a problem of minimum; in this first of all is a source of fecund analytic transformations, and be-

sides in the very calculations of the investigation of variations useful indications may appear, relative to the conditions at the limits; a beautiful example of it was given by Kirchoff in the delicate investigation of the conditions at the limits of the equilibrium of flexure of plates.

VI.

I have been led to expand particularly on partial differential equations.

Examples chosen in rational mechanics and in celestial mechanics would readily show the rôle which ordinary differential equations play in the progress of these sciences whose history, as we have seen, has been so narrowly bound to that of analysis.

When the hope of integrating with simple functions was lost, one strove to find developments permitting to follow a phenomenon as long as possible, or at least to obtain information of its qualitative bearing.

For practise, the methods of approximation form an extremely important part of mathematics, and it is thus that the highest parts of theoretic arithmetic find themselves connected with the applied sciences. As to series, the demonstrations themselves of the existence of integrals furnish them from the very first; thus Cauchy's first method gives developments convergent as long as the integrals and the differential coefficients remain continuous.

When any circumstance permits our foreseeing that such is always the case, we obtain developments always convergent. In the problem of n bodies, we can in this way obtain developments valid so long as there are no shocks.

If the bodies, instead of attracting, repel each other, this contingency need not be feared and we would obtain developments valid indefinitely; unhappily, as Fresnel said one day to Laplace, nature is not concerned about analytic difficulties and the celestial bodies attract instead of repelling each other.

One would even be tempted at times to go further than the great physicist and say that nature has sown difficulties in the paths of the analysts.

Thus to take another example, we can generally decide, given a system of differential equations of the first order, whether the general solution is stable or not about a point, and to find developments in series valid for stable solutions it is only necessary that certain inequalities be verified.

But if we apply these results to the equations of dynamics to discuss stability, we find ourselves exactly in the particular case which is unfavorable. Nay, in general here it is not possible to decide on the stability; in the case of a function of forces having a maximum, reasoning classic, but indirect, establishes the stability which can not be deduced from any development valid for every value of the time.

Do not lament these difficulties; they will be the source of future progress.

Such are also the difficulties which still present to us, in spite of so many works, the equations of celestial mechanics; the astronomers have almost drawn from them, since Newton, by means of series practically convergent and approximations happily conducted all that is necessary for the foretelling of the motions of the heavenly bodies.

The analysts would ask more, but they no longer hope to attain the integration by means of simple functions or developments always convergent.

What admirable recent researches have best taught them is the immense difficulty of the problem; a new way has, however, been opened by the study of particular solutions, such as the periodic solutions and the asymptotic solutions which have already been utilized. It is not perhaps

so much because of the needs of practice as in order not to avow itself vanquished, that analysis will never resign itself to abandon, without a decisive victory, a subject where it has met so many brilliant triumphs; and again, what more beautiful field could the theories new-born or rejuvenated of the modern doctrine of functions find, to essay their forces, than this classic problem of n bodies?

It is a joy for the analyst to encounter in applications equations that he can integrate with known functions, with transcendents already classed.

Such encounters are unhappily rare; the problem of the pendulum, the classic cases of the motion of a solid body around a fixed point are examples where the elliptic functions have permitted us to effect the integration.

It would also be extremely interesting to encounter a question of mechanics which might be the origin of the discovery of a new transcendent possessing some remarkable property; I would be embarrassed to give an example of it unless in carrying back to the pendulum the début of the theory of elliptic functions.

The interpenetration between theory and applications is here much less than in the questions of mathematical physics. Thus is explained, that, since forty years, the works on ordinary differential equations attached to analytic functions have had in great part a theoretic character altogether abstract.

The pure theory has notably taken the advance; we have had occasion to say that it was well it should be so, but evidently there is here a question of measure, and we may hope to see the old problems profit by the progress accomplished.

It would not be over difficult to give some examples, and I will recall only those linear differential equations, where figure arbitrary parameters whose singular values are roots of entire transcendent functions; which in particular makes the successive harmonics of a vibrating membrane correspond to the poles of a meromorphic function.

It happens also that the theory may be an element of classification in leading to seek conditions for which the solution falls under a determined type, as for example that the integral may be uniform. There have been and there yet will be many interesting discoveries in this way, the case of the motion of a solid heavy body treated by Mme. de Kovalevski and where the Abelian functions were utilized is a remarkable example.

VII.

In studying the reciprocal relations of analysis with mechanics and mathematical physics, we have on our way more than once encountered the infinitesimal geometry, which has proposed so many celebrated problems; in many difficult questions, the happy combination of calculus and synthetic reasonings has realized considerable progress, as show the theories of applicable surfaces and systems triply orthogonal.

It is another part of geometry which plays a grand rôle in certain analytic researches, I mean the geometry of situation or *analysis situs*. We know that Riemann made from this point of view a complete study of the continuum of two dimensions, on which rests his theory of algebraic functions and their integrals.

When this number of dimensions augments, the questions of *analysis situs* become necessarily complicated; the geometric intuition ceases, and the study becomes purely analytic, the mind being guided solely by analogies which may be misleading and need to be discussed very closely. The theory of algebraic functions of two variables, which transports us into a space of four dimensions, without getting from

analysis situs an aid so fruitful as does the theory of functions of one variable, owes it, however, useful orientations.

There is also another order of questions where the geometry of situation intervenes; in the study of curves traced on a surface and defined by differential equations, the connection of this surface plays an important rôle; this happens for geodesic lines.

The notion of connexity, moreover, presented itself long ago in analysis, when the study of electric currents and magnetism led to non-uniform potentials; in a more general manner certain multiform integrals of some partial differential equations are met in difficult theories, such as that of diffraction, and varied researches must continue in this direction.

From a different point of view, I must yet recall the relations of algebraic analysis with geometry, which manifest themselves so elegantly in the theory of groups of finite order.

A regular polyhedron, say an icosahedron, is on the one hand the solid that all the world knows; it is also, for the analyst, a group of finite order, corresponding to the divers ways of making the polyhedron coincide with itself.

The investigation of all the types of groups of motion of finite order interests not alone the geometers, but also the crystallographers; it goes back essentially to the study of groups of ternary linear substitutions of determinant $+1$, and leads to the thirty-two systems of symmetry of the crystallographers for the particular complex.

The grouping in systems of polyhedra corresponding so as to fill space exhausts all the possibilities in the investigation of the structure of crystals.

Since the epoch when the notion of group was introduced into algebra by Galois, it has taken, in divers ways, considerable development, so that to-day it is met in all parts of mathematics. In the applications, it appears to us above all as an admirable instrument of classification. Whether it is a question of substitution groups or of Sophus Lie's transformation groups, whether it is a question of algebraic equations or of differential equations this comprehensive doctrine permits explanation of the degree of difficulty of the problems treated and teaches how to utilize the special circumstances which present themselves; thus it should interest as well mechanics and mathematical physics as pure analysis.

The degree of development of mechanics and physics has permitted giving to almost all their theories a mathematical form; certain hypotheses, the knowledge of elementary laws, have led to differential relations which constitute the last form under which these theories settle down, at least for a time. These latter have seen little by little their field enlarge with the principles of thermodynamics; to-day chemistry tends to take in its turn a mathematical form.

I will take as witness of it only the celebrated memoir of Gibbs on the equilibrium of chemical systems, so analytic in character, and where it needed some effort on the part of the chemists to recognize, under their algebraic mantle, laws of high importance.

It seems that chemistry has to-day gotten out of the premathematic period, by which every science begins, and that a day must come when will be systematized grand theories, analogous to those of our present mathematical physics, but far more vast, and comprising the ensemble of physicochemic phenomena.

It would be premature to ask if analysis will find in their developments the source

of new progress; we do not even know beforehand what analytic types one might find.

I have constantly spoken of differential equations ruling phenomena; will this always be the final form which condenses a theory? Of this I know nothing certain, but we should, however, remember that many hypotheses have been made of nature more or less experimental; among them, one is what has been called the principle of *non-heredity,* which postulates that the future of a system depends only on its present state and its state at an instant infinitely near, or more briefly that accelerations depend only on positions and velocities.

We know that in certain cases this hypothesis is not admissible, at least with the magnitudes directly envisaged; one has sometimes misemployed on this subject the memory of matter, which recalls its past, and has spoken in affected terms of the life of a morsel of steel. Different attempts have been made to give a theory of these phenomena, where a distant past seems to interfere; of them I need not speak here. An analyst may think that in cases so complex it is necessary to abandon the form of differential equations, and resign oneself to envisage *functional equations,* where figure definite integrals which will be the witness of a sort of heredity.

To see the interest which is attached at this moment to functional equations, one might believe in a presentiment of the future needs of science.

VIII.

After having spoken of non-heredity, I scarcely dare touch the question of the applications of analysis to biology.

It will be some time, no doubt, before one forms the functional equations of biologic phenomena; the attempts so far made are in a very modest order of ideas; yet efforts are being made to get out of the purely qualitative field, to introduce quantitative measures. In the question of the variation of certain characteristics, mensuration has been engaged in, and statistic measures which are translated by curves of frequency. The modifications of these curves with successive generations, their decompositions into distinct curves, may give the measure of the stability of species or of the rapidity of mutations, and we know what interest attaches itself to these questions in recent botanic researches. In all this so great is the number of parameters that one questions whether the infinitesimal method itself could be of any service. Some laws of a simple arithmetic character like those of Mendel come occasionally to give renewed confidence in the old aphorism which I cited in the beginning, that all things are explained by numbers; but, in spite of legitimate hopes, it is clear that, in its totality, biology is still far from entering upon a period truly mathematical.

It is not so, according to certain economists, with potential economy. After Cournot, the Lausanne school made an effort extremely interesting to introduce mathematical analysis into political economy.

Under certain hypotheses, which fit at least limiting cases, we find in learned treatises an equation between the quantities of merchandise and their prices, which recalls the equation of virtual velocities in mechanics: this is the equation of economic equilibrium. A function of quantities plays in this theory an essential rôle recalling that of the potential function. Moreover, the best authorized representatives of the school insist on the analogy of economic phenomena with mechanical phenomena. "As rational mechanics, says one of them, considers material points, pure economy considers the homo œconomicus."

Naturally, we find there also the ana-

logues of Lagrange's equations, indispensable matrix of all mechanics.

While admiring these bold works, we fear lest the authors have neglected certain hidden masses, as Helmholtz and Hertz would have said. But although that may happen, there is in these doctrines a curious application of mathematics, which, at least in well-circumscribed cases, has already rendered great services.

I have terminated, messieurs, this summary history of some of the applications of analysis, with the reflections which it has at moments suggested to me.

It is far from being complete; thus I have omitted to speak of the calculus of probabilities, which demands so much subtlety of mind, and of which Pascal refused to explain the niceties to the chevalier de Méré because he was not a geometer.

Its practical utility is of the first rank, its theoretic interest has always been great; it is further augmented to-day, thanks to the importance taken by the researches that Maxwell called *statistical* and which tend to envisage mechanics under a wholly new light.

I hope, however, to have shown, in this sketch, the origin and the reason of the bonds so profound which unite analysis to geometry and physics, more generally to every science bearing on quantities numerically measurable.

The reciprocal influence of analysis and physical theories has been in this regard particularly instructive.

What does the future reserve?

Problems more difficult, corresponding to an approximation of higher order, will introduce complications which we can only vaguely forecast, in speaking, as I have just done, of functional equations replacing systematically our actual differential equations, or further of integrations of equations infinite in number with an infinity of unknown functions. But even though that happens, mathematical analysis will always remain that language which, according to the *mot* of Fourier, has no symbols to express confused notions, a language endowed with an admirable power of transformation and capable of condensing in its formulas a number immense of results.

EMILE PICARD.

PRESENT PROBLEMS OF METEOROLOGY.*

NEVER in the history of the science have so many problems presented themselves for solution as at the present time. Numerous *a priori* theories require demonstration and, in fact, the whole structure of meteorology, which has been erected on hypotheses, needs to be strengthened or rebuilt by experimental evidence. Until recently the observations have been carried on at the very bottom of the atmosphere and our predecessors have been compared justly to shell-fish groping about the abysses of the ocean floor to which they are confined.

Probably meteorology had its origin in a crude system of weather predictions, based on signs in the heavens, and it did not become a science until the invention of the principal meteorological instruments in the seventeenth century made possible the study of climatology by the collection of exact and comparable observations at many places on the globe. These data, owing to extensive operations of the meteorological services in the different countries, are now tolerably complete, there being comparatively small portions of the land-surface, at least, for which the climatic elements are not fairly well known, the gaps that remain to be filled lying chiefly on the Antarctic continent and in the interior of Africa.

Although it is about fifty years ago since the first observations, made synchronously

* Address at St. Louis to the Section of Cosmical Physics of the International Congress of Arts and Science.

over a considerable territory, were telegraphed to a central office for the purpose of forecasting the weather, it must be confessed that practically no progress has been realized in this art, for, while much has been done to complete and extend the area under observation by the creation of a finer and larger network of stations, and while the transmission of the observations and the dissemination of the forecasts based on them have been accelerated, the methods employed in formulating the forecasts are essentially those empirical rules which were adopted at the inception of the work. A recent extension of the field of observation over the ocean, by wireless telegraphy, may here be mentioned as offering advantages to certain countries; for example, the reports now being received in England from steamers in mid-Atlantic give information about the approaching weather conditions—subject, of course, to any subsequent changes—long before they reach the western shores of the British Isles. Nevertheless, the data obtained still relate mainly to the lowest strata of the atmosphere and we are ignorant of the conditions that prevail at the height of a mile or two both during storms and in fine weather. Until these are known and their sequence in the upper and lower atmosphere has been established by careful investigation, our weather forecasts based on synoptic observations will continue to be largely empirical. However, it should be remembered that since weather predictions constitute the aspect of meteorology which most appeals to mankind, the incentive to improve them is the most likely to stimulate the investigations needed. Therefore, it is the problems of dynamic meteorology that now press for solution, and to achieve this purpose we must not only look upward, but also elevate ourselves, or our instruments, into the higher regions.

This mode of study belongs entirely to the last half-century, for only within that period has a systematic attempt been made to ascertain the conditions prevailing in the upper air. To the credit of the United States it should be remembered that the first post of observation upon a mountain peak was one established in 1871 upon Mount Washington, in New Hampshire, and this was soon followed by the highest observatory in the world, maintained during fifteen years upon the summit of Pike's Peak in Colorado. The observatory upon the Puy de Dôme in France, opened in 1876, was the first mountain station in Europe to be equipped with self-recording instruments. A large amount of data has been collected at these stations which illustrate chiefly the climatology of the mountainous regions, for what we obtain in this way still pertains to the earth and, as is now admitted, does not represent the conditions prevailing at an equal height in the free air. During the present century, the organized efforts which have been made to explore the ocean of air above us have already resulted in a great increase of knowledge respecting the atmosphere as a whole. This task of ascertaining the conditions of the free air was resumed in 1888, with balloon ascents in Germany, in which special precautions were taken to obtain accurate temperatures, previous observations in balloons leaving much to be desired in this respect. In France, about 1892, it was demonstrated that by means of balloons carrying only self-recording instruments, meteorological information might be acquired at heights far greater than those to which a human being can hope to ascend and live. The use of the so-called *'ballons-sondes,'* liberated and abandoned to their fate, with the expectation that when they fall to the ground the records will be recovered, was soon adopted in Germany and has since spread

all over Europe. It has been introduced into the United States by the writer, who has just despatched the first of these registration-balloons from St. Louis, hoping in this way to obtain the temperatures at heights never before reached above the American continent.

In 1894, at the Blue Hill Observatory, near Boston, kites were first used to lift self-recording instruments and so obtain graphical records of the various meteorological elements in the free air, and this method of observation, which presents the great advantage of securing the data in the different atmospheric strata almost simultaneously and nearly vertically above the station on the ground, has been extensively employed both in this country and abroad. Heights exceeding three miles have been attained and it is possible to ascend a mile or two on almost any day when there is wind. To render the method independent of this factor, the plan of flying kites from a steamship was introduced by the writer three years ago, and this scheme, too, is now being successfully employed in Europe. The exploration of the free air by balloons and kites, it may be remarked, has given rise to the construction of special types of light and simple self-recording instruments, which are capable of recording automatically the values of temperature, moisture and wind with a precision comparable to the eye-readings of standard instruments by a good observer.

Having described some of the newer methods of meteorological investigation, let us now consider how they may help to solve certain problems in dynamic meteorology. It should be premised that, since the atmosphere is relatively a thin layer with respect to the globe which it covers, no portion of it can be regarded as independent of another and, consequently, a weather-map of the whole globe, day by day, is of prime importance. Were this provided, the atmospheric changes occurring simultaneously in both hemispheres could be watched and their relation to what have been called 'the great centers of action,' investigated. Thanks to the increasing area covered by reports from the various weather services, the unmapped surface of the globe is being diminished, so that a complete picture of the state of the atmosphere each day over the land is gradually coming into view.

The mathematical application of the theory of a rotating sphere, surrounded by a heated atmosphere, to explain the circulation of the atmosphere as we find it, has not been satisfactory, owing to our lack of knowledge of the conditions of the upper air, as well as our ignorance concerning the physical properties of the atmosphere itself. To acquire the latter knowledge, research laboratories must be established at selected points, at both high and low levels, and as subjects of study there may be mentioned the determination of the amount of heat received from the sun and its secular variation, if any, the radiating and absorbing power of the air, the relation of pressure, density and temperature, the chemical composition of the air, its ionization and radioactivity, and other investigations which have been proposed by Professors Abbe and McAdie in their pleas for the creation of such aerophysical laboratories. The observatory now under construction by the United States Weather Bureau on a mountain in Virginia will, it is hoped, enable some of these problems to receive the attention which they deserve.

The average circulation of the lower atmosphere is now well known, by reason of the monumental work of Lieutenant Maury on the winds over the oceans, and from the mass of data since collected over oceans and continents through the meteorological organizations of the various coun-

tries. While, naturally, much less is known regarding the circulation of the upper air, a great deal has been ascertained from the observations of clouds that were instituted a few years ago in various parts of the world by an international committee. In order to insure that the same cloud should everywhere be called by the same name, it was necessary to instruct the observers by publishing a cloud-atlas, containing pictures and descriptions of the typical forms of clouds which experience has shown to be identical all over the globe. Then during one year which had been agreed upon, measurements of the direction of drift and the apparent velocity of the several cloud-types were made at many stations, and measurements, by trigonometrical or other methods, of the height of these clouds above a few selected stations enabled the true velocity of the air-currents to be determined up to the altitude at which the cirrus clouds float. Thus an actual survey of the direction and speed of the atmospheric circulation at different levels was effected, and a recent discussion of the results by Professor Hildebrandsson shows that the theories which have been held heretofore are untenable. Professor Hildebrandsson's conclusions in brief are that there is no exchange of air between poles and equator, the circulation over the oceans, at least, resolving itself into four great whirls, the air which rises above the tropics flowing over the trades and descending probably in the extra-tropical regions, while around each pole is an independent cyclonic circulation. Although this general circulation of the atmosphere appears to be indicated, many details require to be investigated. In particular, the movements of the great masses of air overlying the trade winds and doldrums, which is a region nearly barren of clouds, are still unknown and the determination of these movements, as well as the temperature and humidity of the different strata, by means of kites flown from steamships, was suggested by the writer, since it would be possible in this way to penetrate even the masses of quiescent air which probably separate the trade winds from the superposed antitrades. This suggestion has already been put in practise on the yacht of the Prince of Monaco in the neighborhood of the Azores, but a more extensive campaign is necessary, which the writer himself hopes to undertake, if the funds necessary to charter and equip a steamer can be procured.

Here it will be encouraging to state some results of the efforts to ascertain the vertical thermal and hygrometric gradients in the atmospheric ocean, and to show what may be accomplished in the future. Observations on mountains, as we have seen, can not be expected to give the conditions which exist at the corresponding heights in the free air and hence the necessity of sending observers or self-recording instruments into this medium through the agency of balloons and kites. By the aid of an international committee formed eight years ago under the direction of Professor Hergesell at Strassburg, much has been accomplished in Europe in this way, and something in this country through kite-flights. At the present time such atmospheric soundings are made once a month in most European countries, and at Blue Hill in the United States, with the result that a knowledge is being acquired of the vertical gradients of the meteorological elements which entirely contradicts previous conceptions. For example, it was formerly supposed that the temperature diminished with increasing altitude more and more slowly and that at a height of about ten miles it remained invariable during winter and summer and above pole and equator. But the recent investigations of my colleagues in France and Germany show that the temperature

decreases faster and faster as one rises in the air and that not only is there a large seasonal variation at the greatest heights attained, but that non-periodic changes occur from day to day, as they do at the earth's surface. Still more remarkable is the indication of a warm current at a height of about seven miles, while the stratification of the atmosphere as regards temperature, moisture and wind has been shown by the kite-flights at Blue Hill to be a normal condition, and not merely confined to the high atmosphere as was formerly supposed. Daily soundings of the atmosphere to the height of a mile or two are now being made with kites and captive balloons at the meteorological institutes of Berlin, Hamburg and St. Petersburg, and are furnishing valuable data concerning the changes in the meteorological elements which occur simultaneously or successively in the overlying strata.

Of the various unsolved questions relating to this subject perhaps the most important is whether the core of the cyclone possesses the excess of temperature over the surrounding body of air which the convectional theory of its origin requires. We need to know also the height to which the cyclone extends, the circulation around it at various levels, and further to generalize the theory of an accompanying cold-center cyclone in the upper air, deduced by Mr. Clayton from the Blue Hill observations. Other vexed questions can be elucidated by similar researches, such as the conditions favorable for precipitation and the action of dust-nuclei in producing it, the source of our American cold-waves, the exact relations of thunderstorms and tornadoes to centers of pressure and temperature and, finally, the causes which, in the upper air, influence the trajectories and velocities of the cyclones and anti-cyclones that give us our broader weather features. When these correlations are determined from the investigations of the free air now in progress, and we possess a sufficient number of aerial stations to make it possible to chart a daily map of the upper air, then we may expect an improvement in the weather forecasts. The prediction of fog over the ocean on, and adjacent to, our coasts is of great practical importance to shipping, especially off the banks of Newfoundland, and the writer believes that meteorological kites flown from a steamer in these regions would reveal the unknown relations of temperature, humidity and wind in and above the fog-bank which might lead to the prediction of the conditions favorable to its formation.

We now pass to another branch of meteorological research, namely, the cosmical relations. It is incontestable that the sun, the source of all terrestrial energy, has great influence upon the magnetic conditions of the earth, but a consideration of the relation of terrestrial magnetism and meteorology will be left to my colleague, Dr. Bauer. The cause of atmospheric electricity has always been an enigma to meteorologists, but the discovery of 'ions,' or 'electrons,' as carriers of electricity, has thrown some light on this question. It is of importance in geophysics to know how the capacity of the air for positive and negative electrons varies with altitude, and also the periodic and non-periodic variation of the potential at the earth's surface.

Attempts to regard all atmospheric phenomena as periodic and due to the influence of the sun or moon have long occupied the attention of eminent investigators, but it must be admitted that the effects of neither the periods of solar nor those of lunar rotation upon the earth's meteorology can be claimed to have been proved, although a correspondence has been found by the distinguished speaker who preceded me in regard to the frequencies of auroras and

thunderstorms and the position of the moon in declination. To Professor Arrhenius is also due the remarkable generalization that the pressure of light emanating from the sun causes alike the streaming away from it of comets' tails, the zodiacal light and the aurora borealis. The relation of sunspot frequency, which has a periodicity of about eleven years, to atmospheric changes on the earth, especially as manifested by barometric pressure, rainfall and temperature in India, has been investigated, and the coincidences, even if nothing more, which have been shown to exist by Sir Norman Lockyer and his son are suggestive. It may be pointed out that the same action of the sun might cause simultaneously increased rainfall in India and a deficiency of rainfall in England, because rising currents in one region are necessarily accompanied by descending currents elsewhere, and, therefore, no objection can be offered to a theory of cosmical influence which produces different weather conditions in different parts of the globe.

Since the sun is the source of our energy, the discovery of any variation in the heat emitted is of the deepest interest and the important investigations of Professor Langley are now to be supplemented by the broader work of a committee appointed by the National Academy of Sciences and also by an international committee, with the general object of combining and discussing meteorological observations from the point of view of their relation to solar phenomena. It does not seem improbable, therefore, that eventually we may have seasonal predictions of weather, possessing at least the success of those now made daily, and that possibly forecasts of the weather will be hazarded several years in advance. The value of such forecasts, as affecting the crops alone, would be of inestimable benefit to mankind, and predictions already made in India for the ensuing season, while not entirely successful, have still proved advantageous. A number of short cycles in the weather have been detected, including a seven-day period in the temperature, which Mr. Clayton found could be used for forecasting were it not for an unexplained reversal in the phase of the temperature oscillation.

The interesting question of the value of meteorological observations may appropriately conclude this address. Professor Schuster, the English physicist, has recently denounced the practice of accumulating these observations with no specific purpose. To an extent this criticism is valid in all the sciences, since those observations are most useful when made by or for the person who is to utilize them, but although modern meteorology demands special series of observations to solve such problems as the temperature in cyclones and anticyclones, it is sometimes true that long series of observations made with one object in view may subsequently become valuable for quite another purpose. For the study of climate and its possible change, long-continued observations in each country are a necessity, though these might properly be confined to selected stations from whose normals the values for other stations may be computed. Professor Schuster's wish to limit the number of observations implies that the existing series have been inadequately discussed, for the reason that it is easier to find observers than competent investigators. For this unfortunate condition the weather services of most countries are chiefly to blame, because, being burdened with the routine work of collecting climatological and synoptic data and formulating and promulgating weather forecasts, which is the public estimate of their entire duty, most government meteorological organizations concentrate their energies and expenditures on these functions and par-

tially or completely neglect the researches by which alone our knowledge of the mechanics of the atmosphere can be increased. In this criticism must be included the United States Weather Bureau (exception being made in favor of Professor Bigelow's discussions), and the similar bureaus of such equally enlightened countries as France and England. However, in the latter country an attempt is now being made to create an Imperial meteorological institute which could undertake the discussion of the great mass of data accumulated in Great Britain and her colonies, especially the relations of solar phenomena to meteorology and magnetism, and it is argued that this would contribute towards the formation of a body of scientific investigators adequate to the needs of the British Empire and be of the highest educational and scientific worth. In the United States, meteorological research has always been fostered by individuals, of whom the names of Franklin, Redfield, Espy, Coffin, Maury, Loomis and Ferrel are brilliant examples. To-day my colleague, M. Teisserenc de Bort in France, and we ourselves at Blue Hill, are endeavoring, unassisted, to solve problems in dynamic meteorology, which ought to be undertaken by the national services of our respective countries. It behooves then those who are desirous of advancing the status of meteorology to strive to convince the public that the function of a government bureau is not merely to collect meteorological data and to make inductive weather predictions based on remembrance of the sequence in similar conditions, but that the science of meteorology requires laborious researches by competent men and the generous expenditure of money before practical benefit can result from improved weather forecasts. If some of my hearers are converted to such an opinion, this address will have served a useful purpose.

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Blue Hill Meteorological Observatory.

SCIENTIFIC BOOKS.

The Lymphatics. By Poirier, Cunéo and Delamere. Translated and edited by Cecil H. Leaf. Chicago, W. T. Keener & Co. 1904.

The chapters on the 'Lymphatic System' in Poirier's 'Anatomy' have been translated into English and presented in book form by C. H. Leaf. The first half of the book is on the 'General Anatomy of the Lymphatics,' and is by Delamere, while the second half is by Poirier and Cunéo and treats of the 'Special Study of the Lymphatics in Different Parts of the Body.' The translation is thoroughly well done.

The increasing interest in the lymphatic system makes the appearance of such a book especially welcome. It is the most complete and comprehensive monograph on the lymphatic system that we have and will fill a long-felt need. It contains some original work, especially the last half. The two parts are distinct and will be taken up separately.

The plan of the first part is excellent, the subject being treated systematically under four heads, the lymph, the leucocytes, the lymphatic vessels and the glands. Each subject is treated first practically, by giving our definite knowledge about it, and then theoretically. The practical part is excellent, clear, comprehensive, definite and not diffuse. It brings together facts for which one would otherwise have to hunt through many books. The treatment of the theoretical part, on the other hand, is weak. For example, under the lymph, its properties, physical and chemical, are unusually well given; but in the treatment of the theories of the formation of lymph it is not clearly brought out that there are two opposing theories; one that physical forces are sufficient to account for the formation of lymph, and the other that it is a secretion of endothelial cells. It is not shown that the physical theory, which has grown out of the

filtration theory of Claude Bernard, involves not only filtration, but osmosis and diffusion. The arguments for the secretion theory are more fully given, but not well analyzed. For example, Rauvier's observation that the large sacs, which are so characteristic of developing lymphatic capillaries, are filled with a fluid different from blood plasma is given as evidence that this fluid is the result of secretion, while as a matter of fact it is not an argument for one side more than the other.

The subject of the leucocytes is a difficult one to treat. The descriptions of the different types are excellent, much better than in the average text-book, and can not fail to be helpful to the student. Many special points, familiar to one with experience in blood work, but perplexing to the student, are brought out. For example, the difficulty of drawing a sharp line between the small and large mononuclears. The different solubilities of the granulations is another valuable point. The theory of phagocytosis is so identified with the name of Metchnikoff that one is surprised to find but a casual mention of his work in this connection. It also seems a mistake not to mention that in view of the studies on chemiotaxis and immunity our ideas of the physiology of the leucocytes now include much more than phagocytosis.

In regard to the granulations, our author asks of what is the physiological value of distinctions established by color reactions. This point is brought out in a more interesting and fruitful way by Ehrlich in his book on 'Die Anaemie,' when he says that only a part and, perhaps, only a small part, of our knowledge of leucocytes can come from histological studies, that we must turn to experimental work and to pathology for a wider knowledge. However, the classification given by our author is based on the granulations and we believe that it is the best classification that we have. No classification can be thoroughly rational until we know the origin of the leucocytes. The grouping given by Delamere is certainly practical. He divides the leucocytes into five classes: (1) microcytes (lymphocytes), (2) macrocytes (large mononuclears), (3) cells with neutrophilic granules (polymorphonuclears), (4) cells with acidophile granules (eosinophiles), (5) cells with metachromatic basophile granules (mastzellen). This is based as much as possible on the granulations, for the macrocyte has basophile granules and the microcyte is without granules. This classification is also best adapted to the study of bone marrow.

In regard to the theories of the formation of the leucocytes the treatment is again weak. The theory that the leucocytes come from the lymph nodes, and the granular forms from the bone marrow, is attributed to Denys. This theory our author brushes aside on the ground that the leucocytes are present before the bone marrow is formed. This is of course true, just as much as that lymphocytes occur in the thymus before lymph nodes are formed, and that blood cells occur in the blood islands of the area vasculosa entirely outside the body. This theory, as developed by the Ehrlich school, recognizes that there are many places for the development of blood cells in the embryo, but that in the adult the bone marrow gives rise to the granular forms. It can not be considered as proved, but it gives the most fruitful working bases we have at present. It has been built up through a study of the anæmias and leukæmias and it certainly can not be brushed aside without taking into consideration the pathological evidence. It leaves the question of the origin of blood cells from connective tissue open, stating that whether the leucocytes come from preexisting blood cells or from connective tissue cells they are formed in the adult in the lymph nodes and bone marrow. In regard to the origin of the leucocytes from connective tissue our author is dogmatic when he says that it is proved that a leucocyte can become a connective tissue cell, and it is at least very probable that a connective tissue cell can become a white cell. In reality we are waiting for a new way of attacking this problem.

The chapter on the lymphatic vessels is thoroughly interesting and much in advance of the usual text-book, since it is based on the work of Ranvier. It has, however, certain mistakes of Ranvier's. It is as clear a statement of the subject as could be given without

a knowledge of the true morphology of the lymphatic system. For example, the question of whether the lymphatics have an especial relation to the serous cavities is wholly cleared up on the basis of the lymphatic vessels being modified veins rather than modified tissue spaces. This section has two excellent pictures of lymphatic capillaries—on pages 74 and 76. They are both thoroughly characteristic and hard to reconcile with Sappey's figure of the lymphatic vessels in the skin given in the same section. In regard to the question of open and closed lymphatics our author is again dogmatic, stating that the lymphatic capillaries are invariably absolutely closed. The recent embryological studies agree that the lymphatic capillaries develop as closed ducts; this, however, does not prove that they are always closed, nor closed in all parts of the body. We may admit that openings have not been demonstrated and that lymphatic capillaries can be injected without extravasation, but how do we explain how the granules of coal pigment get from the air sacs of the lung into the lymph nodes. Experimental evidence obtained from injecting granules into the abdominal cavity is certainly against the idea that all of the granules are carried into the lymphatics by leucocytes. In other words, our histology of the lymphatic capillaries is not yet adequate to explain our physiology, and until it is it is safer not to be dogmatic on the subject of open and closed lymphatics.

In connection with the lymph nodes no one has yet given us such clear pictures as His and we can not but think that this chapter would be improved were it based on his work. A good picture of the connective tissue framework of the node would add much to the clearness of the descriptions. The comparison of lymph nodes in different animals is helpful and the chapter contains many suggestive points.

In general, the first part of the book is an excellent compilation of the facts. It gives a complete literature, but in treating of the development of our knowledge of the subject does not bring out which works have marked the important steps in advance. Though it will be a helpful book to students, it will not do for the lymphatic system what Waldeyer's critical review did for the nervous system, that is, give an even clearer picture of the subject than could be obtained from reading original literature.

The last of the book on 'Regional Anatomy' is a higher type. Though based on the work of Sappey it is not a compilation, but presents a number of new and valuable figures. The subject is treated under the following heads: (1) The lymphatics of the lower limb, (2) of the pelvis and abdomen, (3) of the thorax, (4) of the upper limb, (5) of the head and neck, and finally (6) the collecting trunks. The body is thus gone over systematically and numerous points noted where our knowledge is quite inadequate. The subject of absorption from the central nervous system is untouched. This part of the book is not only helpful to the student in giving what is already known, but will form a good starting point for further investigations.

In general the book will give any one who does not have access to the original literature on the subject, to the works of Sappey, Ranvier, His, Fleming and von Recklinhauser an excellent presentation of the subject.

Florence R. Sabin.

The Teaching of Biology in the Secondary School. By Francis E. Lloyd, A.M., and Maurice A. Bigelow, Ph.D., Professors in Teachers College, Columbia University. American Teachers Series. New York, Longmans, Green and Co. 1904. Pp. viii + 491.

Of this book it may certainly be said that it is by the two men who, of all in this country, are best fitted by their official positions and the nature of their work to write it, for the Teachers College is the one educational institution which lays equal stress upon content and upon method. There will be, I believe, no dissent from the opinion that it justifies our expectations. Its title is not precisely descriptive, since it is not one book, but two separate works by different authors devoted to the teaching of botany and zoology respectively. Yet their union here is amply

justified by practical and educational considerations, and is in this case the more fitting since there runs through them both a certain agreement in thought and treatment. Both consist of monographic chapters upon the important phases of their subjects, discussing both their educational theory and their practical applications, enriched by full bibliographies and frequent citations of opinions and authorities. The attempt to analyze the philosophical or psychological basis of the matters under discussion, quite in place in a work intended for teachers, is prominent in both, but especially in the botanical part, where, indeed, it is sometimes carried to a length not easy to follow. But in neither is fact subordinated to theory, and both are notable for their clear, positive, full discussion of the practical phases of their subjects. In reading the book one is impressed again and again by the remarkable advances that have been made of late in the spirit and method of biological teaching, and also by the great amount that has been done, through such books as this and others, for the guidance of the teacher of biology. Obviously the method of the leaders is far ahead of the general practise, and it is the task of the immediate future to bring the latter more closely into touch with the former.

Professor Lloyd's chapters deal with the value of biology in education, with nature study (which requires particular attention in these days of shallow and lying 'nature books'), with the value of botany in secondary education and with the proper content of a botanical course. The author refers to the development of the popular idea which has been so disastrous to the educational interests of this science, that, in the words of a writer of 1829, 'botany is peculiarly fitted for girls' schools, and is admirably adapted to the tastes, feelings and capacities of females'; and all of us will agree with Professor Lloyd that the subject must be made to stand, 'in some part at least, for plain, old-fashioned discipline.' There can be no doubt that it is along this line the educational salvation of the subject must be worked out. When botany and zoology aim to teach the love of nature, or the wisdom of the Creator, or a habit of observation, or anything whatsoever except a knowledge of the facts and a training in the methods of study in those sciences, they are lost. In the chapter on the various types of botanical courses the author gives his strong support to the synthetic course, that which disregards the conventional divisions of the subject and selects the most important parts of the science for educational use, a matter which will be rendered the easier in the future through the rapidly growing disregard of the same conventional boundaries by investigators. It is a question, however, whether our author is not too severe in his judgment upon the 'systematic' course, which, after all, was what the teacher made it, and which gave some, even if not the greatest, opportunity to a teacher of good spirit. Chapters on the method of thought, and upon general principles to be emphasized in this teaching (the *raison d'être* of the limitations of the chapters being not always plain), lead to the most important chapter of the book, the 'detailed discussion of the course in botany for the high school.' This discussion is more detailed, practical and generally excellent than anything heretofore attempted, a notable and new feature being the frequent references to where scientific studies of the commonly used materials may be found. Sections upon the laboratory and its equipment and materials, and upon botanical books complete this valuable work.

Professor Bigelow's part is somewhat more direct and simple in style than his colleague's, chiefly because of a lesser attempt at method analysis. His chapters deal with the educational value, the subject-matter, the laboratory method in the teaching of zoology, and the relation of the animal nature study and human physiology of the elementary school to high school zoology. The author does not minimize, but faces squarely, the practical difficulties of teaching zoology in the high school, which are undoubtedly considerable, and it is interesting to observe that he, like his colleague, argues for more intensity of work in the subject as essential to the realization of its full value. Other chapters deal with the elementary course, the selection of types for study, an outline for an elementary course, zoological

materials, methods, equipment and zoological books, these latter chapters having a direct positive practical character just such as the inquiring teacher must need. In the discussion of the relation of school courses in zoology to college entrance credits in that subject the author argues for an entrance option in zoology, which indeed is wise, since under educational conditions in this country it is well-nigh impossible to secure proper time and attention to a subject in the high school unless it can be counted for college entrance. The author makes the welcome announcement that such an option is being formulated by an authoritative committee, and is to be published, probably early in 1905. The final chapter deals with the teaching of human physiology in the high school, which the author thinks should be combined with the instruction in zoology. It is interesting to observe the temperate but firm stand the author takes upon a subject which scientific men can hardly be expected to speak of with patience —the 'scientific temperance' instruction in schools.

The limits of space forbid more than this inadequate account of the parts of this very sane, modern, scientific and quite admirable book. It is indispensable to the teacher of biology, and it will exert great influence upon future biological teaching. W. F. GANONG.

Outlines of Physiological Chemistry. By S. P. BEEBE, Ph.D., and B. H. BUXTON, M.D. New York, The Macmillan Company. 1904. $1.50.

The title of this work does not correctly describe its contents or define its scope. It contains little physiological chemistry in the ordinary sense of the term. Yet it may prove a very useful handbook as an outline of chemical theories for the use of physiological chemists.

There are many laboratory guides in physiological chemistry now available. These works, however, have in most cases given little space to the theoretical side of the subject. In order, therefore, to repair this deficiency the student must consult the hand-books of physical chemistry and of organic chemistry. In doing so he is apt to overlook those matters which especially concern him, because of the great mass of unfamiliar ideas with which he meets, and because the writers of such works had not his special needs in view. The work before us aims to meet these special needs. It presents in convenient form so much of chemical theory as is essential to the comprehension of the subject matter and present problems of physiological chemistry.

The first chapter (twenty pages) is devoted to that part of physical chemistry which is of especial importance in physiological chemistry—the theory of solution. It explains briefly and clearly the significance of dissociation, chemical equilibrium, osmotic pressure, why reactions take place, and calculation of chemical formulæ. The succeeding four chapters are devoted to organic chemistry. Structural formulæ of the paraffins, and of the nitrogen and cyclical compounds, are given quite fully, and their significance clearly set forth. In chapter VI. sixty pages are devoted to the proteids, their chemical character, in the light of the preceding chapters, being dwelt upon rather than their reactions as in a laboratory guide. Chapter VII., on enzymes, gives an account of this most important subject, which is not so well generalized as is the treatment of the subject matter of earlier chapters. It even encroaches on the domain of the laboratory guide in giving an enzymatic test for the detection of tyrosin. The eighth and final chapter presents diagrams of Ehrlich's side chain theory, and explains their significance for the phenomena of disease and immunity.

The usefulness of this book would have been enhanced by giving at the end of each chapter a list of the works to which the reader might refer for more detailed information.

The typographical work, which in the presentation of diagrams and structural formulæ is of prime importance, is excellent throughout. YANDELL HENDERSON.

YALE MEDICAL SCHOOL.

SCIENTIFIC JOURNALS AND ARTICLES.

THE November Number of the *Journal of Nervous and Mental Disease* opens with an

address delivered at the thirtieth annual meeting of the American Neurological Association held at St. Louis, September 15, 1904, by the president, Dr. Frank R. Fry. Dr. Fry briefly reviewed the growth of neurology as a specialty, dwelling particularly on the part played by America in its later development, and summarizing the history of the organization. In an article on 'Purulent Myelitis, Focal and Disseminated,' Dr. Joseph Collins presents an interesting case of this uncommon disease illustrated by numerous cuts. In an elaborate discussion of 'Hallucinations' Dr. William A. White, after criticizing some current differential definitions of hallucinations and illusions, together with various theories explanatory of the latter, sets forth that arrived at by himself and Dr. Sidis, namely, the 'peripheral theory,' which refers the origin of hallucinations to a pathological process in the end organ. The proceedings of the Chicago Neurological Society for March 24, 1904, are reported in this number, and the 'Periscope' includes the usual abstracts of periodicals, *Archives de Neurologie, Journal de Neurologie, Allgemeine Zeitschrift für Psychiatrie, American Journal of Insanity, Neurologisches Centralblatt, Centralblatt für Nervenheilkunde und Psychiatrie,* and *Revue de Psychiatrie et de Psychologie ' Expérimentale.* 'Miscellany summarizes an article on 'Criminal Types,' by G. C. Speranza in *American Law Register,* for March, 1904. Two books, 'On the Moral Feeble-mindedness of Women,' by Katinka von Rosen, and 'Les Psychonevroses et Leur Traitement Moral,' by Dr. Dubois, are reviewed.

SOCIETIES AND ACADEMIES.

THE CONVOCATION WEEK MEETINGS OF SCIENTIFIC SOCIETIES.

THE American Association for the Advancement of Science, the American Society of Naturalists and the following societies will meet at Philadelphia, Pa., during the week beginning December 24, 1904:

The American Association for the Advancement of Science.—The week beginning on December 27, President, Professor W. G. Farlow; permanent secretary, Dr. L. O. Howard, Cosmos Club, Washington, D. C.; general secretary, President Charles S. Howe, Case School, Cleveland, Ohio; secretary of the council, Professor Clarence A. Waldo, Purdue University, Lafayette, Ind.

Local Executive Committee.—President, Provost Charles C. Harrison; vice-president, Professor Edgar F. Smith; secretary, Dr. Philip P. Calvert; treasurer, Dr. Samuel G. Dixon; chairman of the executive committee, Provost Charles C. Harrison; of the committee on reception and entertainment, Mrs. Charles C. Harrison; of the committee on hotels and boarding houses, Professor Amos P. Brown; of the committee on meeting places and equipment, Professor Edwin G. Conklin; of the committee on press and printing, Mr. George E. Nitzsche; of the committee on transportation, Mr. Walter Wood; of the committee on finance, Mr. S. F. Houston.

Section A, Mathematics and Astronomy.—Vice-president, Professor Alexander Ziwet, University of Michigan; Secretary, Professor L. G. Weld, University of Iowa, Iowa City, Iowa.

Section B, Physics.—Vice-president, Professor Wm. F. Magie, Princeton University; Secretary, Professor Dayton C. Miller, Case School of Applied Science, Cleveland, Ohio.

Section C, Chemistry.—Vice-president, Professor Leonard P. Kinnicutt, Polytechnic Institute, Worcester, Mass.; secretary, Professor Charles L. Parsons, New Hampshire College of Agriculture, Durham, N. H.

Section D, Mechanical Science and Engineering.—Vice-president, Professor David S. Jacobus, Stevens Institute, Hoboken, N. J.; secretary, Professor Wm. T. Magruder, Ohio State University, Columbus, Ohio.

Section E, Geology and Geography.—Vice-president, Professor Eugene A. Smith, University of Alabama; secretary, Dr. Edmund O. Hovey, American Museum of Natural History, New York, N. J.

Section F, Zoology.—Vice-president, Dr. C. Hart Merriam, U. S. Dept. of Agriculture; secretary, Professor C. Judson Herrick, Denison University, Granville, Ohio.

Section G, Botany.—Vice-president, Professor B. L. Robinson, Harvard University; Secretary, Professor F. E. Lloyd, Teachers College, Columbia University, New York, N. Y.

Section H, Anthropology.—Vice-president, Dr. Walter Hough, U. S. National Museum; secretary, George H. Pepper, American Museum of Natural History.

Section I, Social and Economic Science.—Vice-president Martin A. Knapp, U. S. Interstate

Commerce Commission, Washington; Secretary, Dr. J. F. Crowell, Bureau of Statistics, Washington, D. C.

Section K, Physiology and Experimental Medicine.—Vice-president, Professor H. P. Bowditch, Harvard University.

The American Society of Naturalists.—December 27, 28. President, Professor E. L. Mark, Harvard University; secretary, Dr. Chas. B. Davenport, Station for Experimental Evolution, Cold Spring Harbor, Long Island, N. Y.

The Astronomical and Astrophysical Society of America.—December 28, 29. President, Professor Simon Newcomb; secretary Professor Geo. C. Comstock, Washburn Observatory, Madison, Wis.

The American Physical Society.—December 30. President, Professor Arthur G. Webster; secretary, Professor Ernest Merritt, Cornell University, Ithaca, N. Y.

The American Chemical Society.—December 28–31. President, Professor Arthur A. Noyes, Massachusetts Institute of Technology; secretary. Professor William A. Noyes, the Bureau of Standards, Washington, D. C.

The Geological Society of America.—December 29–31. President, Professor J. C. Branner, Stanford University; secretary, Professor Herman L. Fairchild, Rochester, N. Y.

The Botanical Society of America.—December 27–31. President, F. V. Coville; secretary, Dr. D. T. MacDougall, N. Y. Botanical Garden, Bronx Park, New York City.

The Society for Plant Morphology and Physiology.—December 28, 29, 30. President, Dr. G. T. Moore, Department of Agriculture, Washington; secretary, Professor W. F. Ganong, Smith College, Northampton, Mass.

The Botanical Club of the Association.

The Fern Chapter.

Sullivant Moss Chapter.

Wild Flower Preservation Society of America.

The Society for Horticultural Science.—President, Professor L. H. Bailey, Cornell University; secretary, S. A. Beach, Geneva, N. Y.

The Society for the Promotion of Agricultural Science.—December 26. Secretary, Professor F. M. Webster, University of Illinois, Urbana, Ill.

The Association of Plant and Animal Breeders.

The Association of Economic Entomologists.—President, Professor A. L. Quaintance, Washington, D. C.; secretary, Professor H. E. Summers, Ames, Iowa.

The Entomological Club of the Association.

The American Society of Zoologists (Eastern Branch).—December 27, 28. President, Professor E. A. Andrews, Johns Hopkins University; secretary, Professor Gilman A. Drew, University of Maine.

The American Society of Vertebrate Paleontologists.—December 28–30. President, Professor H. F. Osborn, Columbia University; secretary, Dr. O. P. Hay, American Museum of Natural History, New York City.

The Society of American Bacteriologists.—President, Professor F. G. Novy, University of Michigan; secretary, Professor F. P. Gorham, Brown University, Providence, R. I.

The American Physiological Society.—December 27, 28. President, Professor R. H. Chittenden, Yale University; secretary, Professor Lafayette B. Mendel, New Haven, Conn.

The Association of American Anatomists.—December 26, 27, 28. President, Professor Charles S. Minot, Harvard Medical School; secretary, Professor G. Carl Huber, 333 East Ann St., Ann Arbor, Mich.

American Folk-Lore Society.

The American Anthropological Association.—December 27–Jan. 2. President, Dr. W J McGee, Washington; secretary, Dr. Geo. Grant MacCurdy, Yale University, New Haven, Conn.

The American Psychological Association.—December 28, 29. President, Professor William James, Harvard University; secretary, Professor Livingston Farrand, Columbia University, New York City.

The American Philosophical Association.—December 28, 29, 30. President, Professor George T. Ladd, Yale University; secretary, Professor H. N. Gardiner, Northampton, Mass.

The Sigma Xi Honorary Scientific Society.—President, Professor S. W. Williston, University of Chicago; secretary, Professor Edwin S. Crawley, University of Pennsylvania, Philadelphia, Pa.

THE OHIO ACADEMY OF SCIENCE.

THE fourteenth annual meeting of the academy was held in Cleveland at Adelbert College on November 25–26. The program was somewhat shorter than for preceding meetings but was unusually interesting, especially the longer papers of the first half day's session. The address of the retiring president, E. L. Moseley, was one of the best ever presented to the academy. In it he traced the formation of Sandusky Bay and gave detailed evidences of the growth of Cedar Point. The paper by Professor George Bruce Halsted on

'Mathematics and Biology' was of especial interest at this time on account of its bearing upon the principle of variation and mutation.

The recently adopted rule of not allowing papers to go on the program unless an abstract had been handed in by the author was adhered to by the program committee. This committee was enlarged for the coming year so as to have five members, one for zoology, one for botany, one for geology and physiography, one for archeology, anthropology and ethnology, and one for mathematics, chemistry and physics.

The next annual meeting will be held at the University of Cincinnati during the Thanksgiving recess, 1905. The following officers were elected:

President—Herbert Osborn, Columbus.

First Vice-President—C. W. Dabney, Cincinnati.

Second Vice-President—F. M. Comstock, Cleveland.

Secretary—L. B. Walton, Gambier.

Treasurer—J. S. Hine, Columbus.

Member Board of Trustees—C. J. Herrick, Granville.

Elective Members Executive Committee—S. H. Williams, Oxford, and F. C. Waite, Cleveland.

The annual contribution of $250 to the research fund of the society was again furnished by Emerson McMillin. The following papers were read:

E. L. MOSELEY, Sandusky High School: President's address, 'The Formation of Sandusky Bay and Cedar Point.'

PROFESSOR GEORGE B. HALSTED, Kenyon College: 'Mathematics and Biology.'

PROFESSOR D. C. MILLER, Case School of Applied Science: 'Radium' (illustrated).

PROFESSOR FRANCIS H. HERRICK, Western Reserve University: 'The Building Habits and Home Life of Birds' (illustrated from original photographs).

A. A. WRIGHT, Oberlin College: 'Episodes in the Development of Rocky River.'

JAMES S. HINE, Ohio State University: 'Some Ohio Mammals.'

A. A. WRIGHT: 'Our Smallest Carnivore (*Putorius Allegheniensis*),' with exhibition of specimen.

JOSUA LINDAHL, Cincinnati: 'A List of Isopoda from Ohio.'

HERBERT OSBORN, Ohio State University: 'Report of Progress in the Study of the Hemiptera of the State.'

L. B. WALTON, Kenyon College: 'A Land Planarian in Ohio.'

MISS LUMINA C. RIDDLE: 'The Protozoa of Brush Lake.'

L. B. WALTON: '*Actinolophus minutus*, a New Heliozoan, with a Review of the Species Enumerated in the Genus.'

F. L. LANDACRE, Ohio State University: 'Report of Progress on the Survey of the Protozoa of Sandusky Bay and Vicinity.'

F. L. LANDACRE: 'Note on the Rate of Growth in Stalked Infusoria.'

F. L. LANDACRE,
Retiring Secretary.

THE SCIENCE CLUB OF NORTHWESTERN UNIVERSITY.

THE Science Club of Northwestern University held its regular monthly meeting December 2.

Professor A. V. E. Young, of the department of chemistry, gave a paper on 'Mendeleef's Conception of the Ether.' Mr. J. N. Pearce, of the same department, discussed 'Colloidal Metal Solutions.' Both papers were followed by a general discussion. FLOYD FIELD,
Secretary.

DISCUSSION AND CORRESPONDENCE.

CONVOCATION WEEK.

IN the earlier years of the American Association it had at least four important functions: (1) It gave opportunity for expert scientific discussion. (2) It fostered the scientific spirit and developed scientific interest in the people of the land (*a*) by admitting non-expert as well as expert membership, thus giving an opportunity for non-expert discussion, (*b*) by assembling popular or semi-scientific audiences, (*c*) by a peripatetic system of meetings in which few places were visited more than once. (3) It promoted the solidarity of the scientific body by affording opportunity for personal acquaintance and intercourse (*a*) of students of the same subject, (*b*) of students of different subjects. (4) It undertook the

discussion of general subjects affecting the welfare and interests of the scientific body.

With the growth of the scientific body the experts eventually found their discussions hampered by various conditions growing out of non-expert membership, and special societies were organized. These societies have to a great extent assumed the first of the functions enumerated above, but they ignore the second. Their tendency is toward solidarity of special groups of scientists (3*a*) but against solidarity of the general body (3*b*). They can not perform the fourth function without federation. In the reorganization now in progress the association is becoming the means of federation, the integrating factor; and this relation may be called its fifth function.

The special societies have found, and in the main may be expected to find, the winter more convenient than the summer for their principal meetings. They tend to monopolize convocation week, and by holding the attention of the body of experts interfere, at that time, with the success of the sectional sessions of the association. In view of these and other considerations, it seems to me desirable that the association hold two annual meetings. At a winter meeting, held in conjunction with the affiliated societies, it should function chiefly as the bond of union and the conservator of common interests; its proceedings should include general business, a presidential address and a popular lecture, a few selected papers, or a prearranged discussion on a topic of general interest; and there should be no division into sections. A summer meeting, having for a leading purpose the diffusion of scientific interest, should include the work of sections, popular lectures and excursions.

Under such an arrangement it is not to be supposed that the attendance at the two meetings would be constituted in the same way. The differentiation of work, being an adjustment to the diversity of tastes and needs in the membership, would naturally result in a partial differentiation of personnel. Such a separation is not on all accounts desirable, but it seems to me better than the relinquishment of either of those important functions of the association for which the encroaching special societies fail to make provision.

G. K. Gilbert.

Washington, D. C.,
December 7, 1904.

THE TERM 'GEOLOGY.'

To the Editor of Science: May I trespass once more upon your valuable space to reply to Dr. C. R. Eastman's note in your last number (Science, No. 517), in which he claims to have finally proved me inaccurate in giving credit to De Saussure as the first geologist who used the term 'geology' in the modern acceptation of the word.

While Dr. Eastman and I are quite agreed as to the importance of more care among scientific writers in the citation of ancient authorities, there seems to be this essential difference in our methods. That he is a strict constructionist and clings to the very letter of the law, while I consider it more important to get at the true spirit of the citations, thinking thus to trace more correctly the progress of human thought—a difference which the present case seems to me to well illustrate.

It will be noted that I said De Saussure *appears* to have been the first to use the term geology in writing on his science.

In his 'Lettres Physiques et Morales sur les Montagnes,' published in 1778–9, De Luc, to whom Von Zittel gives priority over De Saussure, uses the term cosmology for the science that treats of the knowledge of the earth, although he says in his preface (page viii) that the proper word would have been geology, but that he 'could not venture to adopt it because it was not a word in use.' De Saussure, on the other hand, writing on the Alps in 1779, employs the term geology without any explanation or apology and alludes to the geologist as if he were a very well-known species of natural philosopher.

In the extremely condensed form in which I was obliged to treat my subject to bring it within the limits of a presidential address, it seemed inadvisable to introduce such explanations as this, hence my use of the word *appears*, implying the possibility of another construction of the statement.

As to the earlier uses of the word given in Murray's 'New English Dictionary,' which, in Dr. Eastman's opinion, furnish a further proof of my want of accuracy, I regard them as proving quite the contrary, as is shown in the following brief analysis of the references under geology.

Richard de Bury's use of the word is defined as 'applied to the study of the law as distinguished from the arts and sciences, which are concerned with the works of God.'

'Geologia' is also the title of an Italian work by F. Sessa, which is intended to prove that the influences ascribed by astrologers to the stars really proceeded from the earth itself. As Murray evidently recognizes, neither of these usages has any relation to modern geology.

He subdivides the later usages of the word geology as (1) 'The science which treats of the earth in general.'

Of those referred to as having used it in this sense, Erasmus Warren (1690) was a Suffolk rector, defending the literal correctness of the Mosaic account of the deluge; B. Martin (1735), a learned optician, who classified rather elaborately the science of his day; and Nathan Bailey (1736) and Dr. Samuel Johnson (1755), lexicographers, who defined it as 'the doctrine of the earth.'

None of these, it is evident, could be considered to be geologists.

It is only Murray's second division—namely, 'the science which has for its object the investigation of the earth's crust, etc.,' which corresponds to the modern acceptation of the word considered in my address, and under this head his first reference is to J. Hutton (1795), who published sixteen years after De Saussure.

Hence, in spite of Dr. Eastman's specious representation of the facts, only a moment's consideration of which he thinks necessary to prove my historical inaccuracy, I still maintain the correctness of my statement, in which I have followed so excellent an authority as Sir Archibald Geikie, who says, in his chapter on De Saussure ('Founders of Geology,' page 88), 'the earliest writer who dignified it [geology] with the name it now bears, was the first great explorer of the Alps.'

S. F. Emmons.

Washington,
November 28, 1904.

THE KELEP AND THE COTTON PLANT.

To the Editor of Science: Professor Wheeler's criticism of Dr. Cook's theory regarding the association of the kelep or Gautemalan ant, with the cotton for its nectar (Science, December 2, page 768) is quite timely. Dr. Cook's theory and the facts upon which it is founded are decidedly unique. In bulletin 49, Division of Entomology, U. S. Dept. of Agriculture, page 64, Professor Cook states that in Texas 'More ants will be necessary, however, for their protection, and the nectar-producing qualities of the different varieties may become a question of practical importance if the kelep should become established.' "At present the nectar secreted on the leaves and squares of the cotton goes to waste, or even serves to attract injurious insects, among them the boll worm moths."

"The discovery of the ant supplies a practical reason for the existence of the nectaries hitherto quite unsuspected, and it suggests the further possibility that the weevil and the ant may have been factors in the evolution of the cotton plant, for the weevil is not known to feed on any plant except cotton." Was the kelep then first attracted to the cotton on account of the nectar or by its appetite for the weevil? That the nectar of the cotton otherwise goes to waste is a surprising statement, inasmuch as a very large proportion of the honey stored by honey bees throughout the southern states is secured from cotton, as is well known to all practical bee keepers. Furthermore, the writer was under the impression that American cotton was originally of oriental origin. If so, how could the kelep and boll weevil have been a factor in the evolution of the cotton plant in the orient where they are not known to occur?

It would seem to the writer that considerably more evidence is necessary to establish such a theory, and that a more intimate knowledge of the cotton plant and the insects

associated with it is highly desirable before it can be stated that nectar at present 'goes to waste.' E. Dwight Sanderson.

New Hampshire College,
Durham, N. H.,
December 6, 1904.

ANENT GIZZARDS.

Professor Eastman* expresses his willingness 'to consign to birds the exclusive enjoyment of gizzards and feathers'; but this seems hardly fair to certain fishes. According to Günther† in the well-known gray mullets (*Mugil*) "the second portion of the stomach reminds one of the stomach of birds; it * * * is globular, and surrounded by an exceedingly strong muscle. This muscle is not divided into two as in birds, but [is] of great thickness in the whole circumference of the stomach, all the muscular fasciculi being circularly arranged. The internal cavity of this stomach is rather small, and coated with a tough epithelium * * *. A low circular valve forms a pylorus." Certainly one can not carp at Drs. Jordan and Evermann‡ for referring to this apparatus as 'gizzard-like,' with which adjective Mr. Barnum Brown contented himself when writing of the plesiosaurs.

The food of the mullets is said§ to consist 'chiefly of the organic substances mixed with mud or sand,' of which they 'take in a quantity.' However, it must also be set down that 'in order to prevent larger bodies from passing into the stomach * * * these fishes have the organs of the pharynx modified into a filtering apparatus' so that 'stomach stones' if present, can never be large. At all events (to state the obvious conclusion) if two such widely separated vertebrates as *Gallus* and *Mugil* have independently evolved gizzard-like modifications of the stomach, why should a similar possibility be denied *à priori* to all reptiles? But whether plesiosaurs were 'lithophagi' or lotus eaters Herodotus saith not.

W. K. Gregory.

American Museum of Natural History.

* Science, N. S., Vol. XX., October 7, 1904, p. 466.

† 'An Introduction to the Study of Fishes,' p. 503.

‡ 'The Fishes of North and Middle America,' Part I., p. 809.

§ Günther, *op. cit.*, p. 502.

NOTE ON THREE VERY LARGE BEAKED WHALES FROM THE NORTH PACIFIC.

To the Editor of Science: Early in November last, I received a letter from President D. S. Jordan, of the Leland Stanford, Jr., University, enclosing a communication from Mr. J. H. Ring, of Ferndale, Humboldt County, California, relative to the stranding of a whale about forty-one feet long near that place. Mr. Ring's letter was accompanied by photographs which made it evident that the animal was one of the ziphioid or beaked whales, of extraordinary size and not in a very good state of preservation. I have recently received additional information from Mr. Ring which makes it certain that the whale belongs to the genus *Berardius*. This genus was first recognized as belonging to the fauna of the North Pacific by Dr. Stejneger, who found a skull on Bering Island in 1882, and, believing it to represent a new species, gave it the name of *Berardius bairdii*. Whether the Ferndale specimen is of that species can not be determined until the skull has been examined.

The specimen is notable as being, so far as I am aware, the first of the genus reported from the Pacific coast of the United States, and further as being the largest beaked whale of which there is any record. In Mr. Ring's second letter, he informed me that he had remeasured the whale and found it to be 43½ feet long. The largest *Berardius* previously known was the type of *B. arnuxii* of New Zealand, which was 32 feet long.

Two large beaked whales were found on the coast of St. George Island, Pribilof Group, Alaska, in June, 1903, by Mr. James Judge, the resident treasury agent. One of these, a female, was reported by Mr. Judge as being 40 feet 2 inches long, and hence only a little smaller than the Ferndale whale. The other specimen, a male, was 25 feet 5 inches long. It is not certain that these Pribilof whales are of the genus *Berardius*, though the in-

formation thus far received points strongly to that conclusion.

The skeletons of these three whales have been secured for the National Museum, and it is my purpose to publish something more in detail regarding them at a later date.

F. W. TRUE.

U. S. NATIONAL MUSEUM,
December 8, 1904.

THE VASCULAR BUNDLES IN AN APPLE.

IT is probably a matter of little significance or importance as to just how many vascular bundles may be found about the core of an apple or how they are distributed. I have seen quite a number of cuts in books and bulletins, but I have never seen one that was right. Any person can soon decide this matter to his own satisfaction, by cutting transverse sections of several varieties of apples and allowing them to begin drying for a few days, when the bundles may be seen sticking out prominently.

W. J. BEAL.

A GEOGRAPHIC DICTIONARY.

IN SCIENCE, November 11, 1904, p. 649, Mr. Cleveland Abbe, Jr., states that he is compiling a dictionary of topographic terms. It may, therefore, be well to draw the attention of him and your other readers to a 'Glossary of geographical and topographical terms and of words of frequent occurrence in the composition of such terms and of place-names, by Alexander Knox, B.A., F.R.G.S., * * * London: Edward Stanford, 12, 13 and 14 Long Acre, W. C., 1904,' price 12*s* 6*d* ($3), being a supplementary volume to 'Stanford's Compendium of Geography and Travel.' This work appears richer in ordinary geographic terms and components of place-names than in technical physiographic terms, and no references are given to literature.

F. A. BATHER.

SPECIAL ARTICLES.

ASTER FORMATION IN ENUCLEATED EGG-FRAGMENTS OF CEREBRATULUS.*

MANY cytologists have accepted the view that the centriole (or centrosome) is a permanent and autonomous organ of the cell, but the direct proof or disproof of this hypothesis is very difficult, owing to the extreme minuteness of the centriole. The attempt to obtain decisive experimental evidence was first made (1901) by E. B. Wilson by shaking unfertilized eggs to pieces and subjecting the fragments to a salt solution. Asters capable of division, containing centrioles, appeared in a large number of the egg-fragments, including both those with and those without a nucleus. It is evidently highly improbable that all these centrioles can be considered as the offspring of preexisting ones, since it is an essential part of the centrosome hypothesis that the organ is primarily single, save when precociously divided into two. Wilson, therefore, came to the conclusion that some, at least, of the centrioles that appeared in such fragments must have been formed *de novo*. This conclusion has since been accepted by some writers, but attacked by others, partly on critical grounds, partly as a result of subsequent experiments in the same direction. A source of error in the experiment undoubtedly existed in the shaking of the eggs to pieces at random. Professor Wilson, therefore, suggested to me nearly two years ago to perform the crucial experiments of cutting the living eggs into two singly and treating the fragments individually. For this purpose the egg of *Cerebratulus* is particularly favorable, since before fertilization the first maturation mitotic figure lies at one pole, where it is seen very definitely in the living object as a clear space. By cutting off this part of the egg, one may be certain that the remaining portion contains no centrioles and, if centrioles appear in this portion of the egg, they must have been formed *de novo*.

I tried this experiment during the summers of 1903 and 1904, with results which are, I believe, decisive. The mode of operation was as follows: all the instruments and the female worm, from which the eggs were taken, were first thoroughly sterilized with fresh water so

* Abstract of a paper read before the meeting of the National Academy of Science, November 15, 1904. In this communication the term 'centriole' is used as equivalent to 'centrosome' in the original sense, *i. e.*, as the dividing and frequently persistent body at the center of the aster.

as to remove all danger of accidental fertilization. The eggs were then allowed to lie in sterilized sea-water for an hour and a half, during which time they showed no sign of having been fertilized. Individual eggs were then cut horizontally, one by one, into an upper nucleated fragment containing the maturation figure, and hence the two centrosomes, and a lower non-nucleated fragment. The latter was subjected to a solution of calcium chloride in sterilized sea-water. After an hour they were replaced in ordinary sterilized sea-water. As a result of this experiment, many, indeed almost all of the non-nucleated fragments produced asters, sometimes single, sometimes in large numbers (in one case more than a score of asters were observed in a single fragment). Many, practically all, asters contained centrioles. No cytasters developed in the control eggs allowed to remain in sterilized sea-water. Sections of the non-nucleated fragments thus treated showed that the asters and centrioles are identical in structure with those of an entire egg subjected to a solution of calcium chloride, while preparations of the corresponding nucleated half demonstrated the presence of the two original centrosomes. No other conclusion, therefore, is possible than that the centrioles of the non-nucleated half have been formed *de novo*. The experiment, I think, verifies the conclusion reached in Wilson's experiment, and is contrary to the negative result recently published by Petrunkewitsch. A detailed presentation of the evidence will be given hereafter.

N. Yatsu.

EARLIEST NOTICE OF AMERICAN PROBOSCIDEA.

The opinion is current and appears to be well founded that vertebrate paleontology in this country had its beginning in Thomas Jefferson's description of 'mammoth' remains from Virginia in 1787,* and of the bones of Megalonyx a dozen years later.

So far as scientific investigation goes, this is undoubtedly true, yet it is interesting to recall that fossil elephant remains have been known from the western world for a much longer period, and from Europe (Sicily) since at least the days of Empedocles of Agrigentum.

* 'Notes on the State of Virginia' (London, 1787).

Not only was Columbus particularly enjoined by the Spanish sovereigns to bring back with him from America all manner of natural products, but in later years Hernandez, private physician to Philip II., and other distinguished functionaries were sent to Mexico for the special purpose of reporting upon the vegetable and zoological curiosities of the country. It was by these travelers, amongst the most prominent of whom besides the afore-mentioned were Oviedo, Acosta and Garcilaso, that fossil proboscidean remains were collected on the elevated plateaux of Mexico, Peru and elsewhere.

Detailed references are given in the second volumes respectively of Cuvier's 'Ossemens Fossiles' and Humboldt's 'Cosmos' to various old Spanish works in which these fossils were described as belonging to a race of human giants, the localities furnishing them being called '*Campos de Gigantes*.' The absurd discussions of '*Teutobochus rex*' in the early part of the seventeenth century are of interest only for revealing the crude state of natural science at that period.

C. R. E.

CURRENT NOTES ON METEOROLOGY.

TEMPERATURE IN CYCLONES AND ANTICYCLONES.

At the 1904 meeting of the British Association, Mr. A. Lawrence Rotch summarized the results of observations obtained at Blue Hill Observatory during 34 kite flights, at different seasons, in areas of high and low pressure, up to about 12,000 feet. The mean decrease of temperature, computed by stages of 1,600 feet, is nearly constant, averaging 1° F. in 376 feet of ascent. Whether the whole column of air in a cyclone is warmer than the corresponding air in an anticyclone (as the convectional theory requires) depends chiefly upon whether its initial temperature at the ground is higher than that of the anticyclone, which is usually the case. If the data obtained from kite flights on consecutive days be plotted for the same height, as was first done at Blue Hill in 1899, it is seen that up to the height of 12,000 feet it is generally warmer at all levels over

areas of low barometric pressure than it is over the adjacent areas of high pressure. Kite flights on Blue Hill are now usually made once a month—upon the day fixed by the International Committee for Scientific Aeronautics.

CYCLONIC DISTRIBUTION OF RAINFALL.

Too much attention has always been paid to the annual, monthly and daily rainfalls, while far too little study has been made of the distribution of rainfall in individual cyclones. Cyclones are not regular in their occurrence, that is true, but they are our great rain-producers and from that point of view they deserve more attention. An important paper by Dr. H. R. Mill, 'On the Unsymmetrical Distribution of Rainfall about the Path of a Barometric Depression,' read before the British Association last August, deserves special mention as an investigation of a kind of which we have far too few. Ten instances of severe and widespread cyclonic rains have been investigated by Dr. Mill, and maps have been drawn showing the amounts of rainfall in each case, and the paths of the depression which brought the rain. It is found that the belt of cyclonic rains is much wider on the left of the path than on the right, and the heaviest falls occur in advance of the center. One of the most remarkable facts discovered is that the widespread cyclonic rains appear to bear no relation to the physical features of the country (*Symon's Met. Mag.*, October, 1904).

MORE LIGHT ON ANTARCTIC METEOROLOGY.

METEOROLOGY is coming to the aid of the geography of the lands in rather an interesting way in the Antarctic. To the *Geographical Journal* for August, Dr. Drygalski, leader of the German Antarctic Expedition, contributes a paper on some of the notable results obtained by the expedition. Dr. Drygalski believes that the new land discovered by the *Gauss*—Kaiser Wilhelm II. Land—is a part of the Antarctic continent, basing his opinion largely upon the meteorological conditions, especially the frequency and uniformity of the easterly gales. These gales have a *fœhn*-like character, and sweep down from the south over the vast, uniform, and but slightly inclined surface of the inland ice. The gales raged through nearly all of May and August, and were numerous in April and September. They even occurred in midsummer, but while they sometimes lasted from three to five days in winter, they only lasted for a day or two in summer. These storms were always accompanied by a heavy snowfall, and were a great obstacle in the way of scientific work.

THE PHYSICS OF THE FREE AIR.

UNDER the general supervision of Drs. Assmann and Hergesell, a new publication has been issued under the title, 'Beiträge zur Physik der freien Atmosphäre,' which is to be devoted to a discussion of the results obtained by means of balloons and kites. Mention has so often been made in these columns of the importance of the meteorological observations made in the free air during the last few years that there is no need of emphasizing the matter further at present. That there should be a field for an independent journal devoted solely to balloon and kite meteorology is very significant. There is a strong corps of associate editors, including Messrs. Rotch and Clayton, of Blue Hill Observatory, who have done so much work in 'sounding the ocean of air' in this country. In the same list we note also the following: Hann, von Bezold, Hildebrandsson, Pernter, Sprung, Abbe, Köppen, Shaw and others. The first number appeared in August, 1904, and is a quarto of 54 pages. The price per volume is 15 Marks.

NOTE.

IT is announced that the arrangement and discussion of the meteorological records obtained by Dr. Sven Hedin during his travels in Central Asia have been intrusted to Dr. Nils Ekholm, of Stockholm. The observations are to be ready for publication at the end of this year; the discussion is expected to appear next spring.

R. DEC. WARD.

THE ISAAC NEWTON STUDENTSHIPS AT CAMBRIDGE.

PROFESSOR G. H. DARWIN writes as follows to the editor of the London *Times:* In 1891

the late Mr. Frank McClean, F.R.S., offered a large sum of money to the University of Cambridge for the foundation of three studentships, to be named after Sir Isaac Newton, for the promotion of the study of astronomy amongst our younger graduates. By the regulations adopted on the acceptance of this large benefaction by the university, the candidates must be under 25 years of age, and the student chosen at each annual election holds his studentship for three years. The income of the fund now amounts to close on £750, so that the stipend payable to each student suffices for his support. Since the object of the endowment was the promotion of scientific research, the students are prohibited from taking any other paid employment; and a succession of young men have thus been enabled to devote three of the best years of their lives to the untrammelled pursuit of science.

The recent death of Mr. McClean has naturally led us at Cambridge to review the effects which have resulted from his generous gift. The records of the electors to the Isaac Newton studentships, of whom I am the secretary, have fully confirmed the prevision of the founder as to the value of such an endowment of research; for we find on the list of past students the names of Professor Sampson, the editor of Adams's papers and director of Durham Observatory, of Mr. Dyson and Mr. Cowell, chief assistants at Greenwich Observatory, and of Mr. Hough, the chief assistant of the observatory at Cape Town. There are besides other past students who have already made their mark in those branches of physics and astronomy which fall within the scope of the endowment.

Mr. McClean was himself fully competent to estimate the effect of his own foundation, for he had attained to the high distinction of the award of the gold medal of the Royal Astronomical Society, which is open to the astronomers of all nations.

The large benefaction of which I have spoken is, however, by no means all that Mr. McClean has done for Cambridge and for other places. Only last year an anonymous donor, whom we now know to have been Mr. McClean, gave a considerable sum for the augmentation, during a period of five years of the stipends of two of the most distinguished of our mathematical lecturers. The foundation of the Stokes and Cayley lectureships, by means of this gift, practically makes a substantial, although temporary, augmentation of the mathematical professoriate of the University. I know from the men who have been nominated to these posts how great is the boon conferred on them, since they now have that leisure for which they had previously longed to devote themselves to science. We hope that the example thus afforded may induce other donors to make this endowment a permanent one.

Mr. McClean had, as the guest of Sir David Gill at the Cape of Good Hope, devoted himself to making a spectroscopic catalogue of southern stars, and he marked his visit to the Cape by presenting a fine telescope to that observatory.

Finally, since his death we learn that he has left a large bequest to the University of Cambridge for the adequate equipment of our observatory with spectroscopic appliances, and further that he has bequeathed to the Fitzwilliam Museum his valuable illuminated manuscripts and printed books, the collection of which formed the amusement of his leisure hours.

We residents at the university think we owe it to the memory of our benefactor to acknowledge the great value which we attach to all that this loyal son of Cambridge has done for us, and, at the same time, to record our sense of the great loss suffered by science and the university by his death.

Such magnificent and wise generosity has unfortunately been but too rare in this country. Is it too much to hope that this example may be followed by others whose wealth enables them to do inestimable service to science and letters by enlightened benefactions?

THE ROYAL SOCIETY.

The Royal Society held its annual meeting on November 30.

The report of the council as summarized in the London *Times* stated that one of the chief

events of the year had been the second general assembly of the International Association of Academies, which was held at Whitsuntide in the rooms of the Royal Society, directing academy of the association for the past three years. The general assembly was attended by seventy delegates, representative of all the constituent academies of the association. The proceedings were reported at the time in these columns, and it will be remembered that Vienna was chosen by a unanimous vote as the place of meeting of the next general assembly. The next subject was the geodetic survey now in progress in South Africa under the control of Sir David Gill. The subject of the extension of the arc beyond the Zambesi was brought up, at the instance of the Royal Society, at the recent meeting of the association in London, and it was hoped to secure the cooperation of the Egyptian government and that the Imperial German government might consent to become responsible for the portion of the arc which would traverse German East Africa. The Russian representative at the International Association expressed the hope that the arc would be ultimately connected through Syria with the Russian network, and thus extend continuously to Lapland; and, in consequence, it was resolved that diplomatic action be taken with a view to the extension of Struve's arc to Egypt. Dr. W. N. Shaw, F.R.S., attended the congress of the International Scientific Commission of Aerostation. The president and council had accepted the permanent duty of nomination to two posts in the supplementary laboratory and hostel which had been established at Col d'Olen, through the agency of Professor Mosso, as an adjunct to the existing International Laboratory of Physiology near the summit of Monte Rosa, and Dr. Ludwig Mond, F.R.S., had given £400 towards the expense of establishing the laboratory. The Royal Society Catalogue of Scientific Papers was in progress, and the last instalment extended from 1884 to 1900. The whole of the second annual issue of the International Catalogue of Scientific Literature had been published, with the exception of the volumes of Botany and Zoology, which were now being printed. The financial support given by the different countries was shown in detail, the total amounting to £6,755. With respect to the government grant for scientific investigations, the treasury had approved the addition of the following clause to the regulations for administering the government grant: "The president and council of the Royal Society may in each year set aside out of the reserve fund such sum as they may consider desirable to provide for any expenditure which may be incurred by the Royal Society (including expenditure on printing, clerks' salaries and office expenses) in undertaking, controlling, supervising or advising upon matters which the president and council may, at the request of the government, undertake, control, supervise or advise upon." Under the regulations the council had, on the recommendation of the Government Grant Committee, made grants this year amounting to £3,194 10s. This amount includes a preliminary grant of £500 to the joint permanent eclipse committee to cover the expense of instruments and preparations for observations of the total solar eclipse of 1905. A sum of £500 had been placed at the disposal of the president and council to meet any pressing demands upon the funds which might be made before the next annual meeting of the government grant committee. The investigation of sleeping sickness in Uganda was continued, after Colonel Bruce's return to England, by Dr. Nabarro and Captain Greig, of the Indian Medical Service. The efforts of the observers were now being directed to the attempt to discover a means of eliminating the trypanosomes from the blood and tissues of the infected in the early stages. In the meantime the Royal Society committee had advised the government to adopt such preventive measures as were found practicable for protecting a non-infected area where the carrier fly was found from the incursion of emigrants from the infected areas. There was next given in the report an account of the *Discovery* Antarctic Expedition, of which the scientific results were now being dealt with in accordance with the scheme agreed upon between the Royal and the Royal Geographical Societies. The two special expert committees were work-

ing as far as possible in concert with the authorities engaged in the reduction of the observations of the German and Scottish Antarctic Expeditions, which in part covered the same period of time. It was proposed that the special scientific results of the expedition should be published in a uniform series of volumes similar to the published records of the *Challenger* Expedition. The subject of Mediterranean fever was referred to the tropical disease committee of the society. At the request of the Colonial Office an advisory board was constituted as a sub-committee of the tropical diseases committee, with Colonel Bruce, F.R.S., as chairman. The president and council had received from the Court of the Goldsmiths' Company a grant of £1,000 'for the purpose of aiding the prosecution of original research work in connection with the character and properties of radium,' accepting the responsibility of the proper application of the grant. In December, 1902, the Lords of the Treasury appointed a committee, under the chairmanship of Sir Herbert Maxwell, F.R.S., M.P., to inquire into and report upon the administration of the parliamentary grant by the Meteorological Council, and to make such recommendations as might seem to them to increase the utility of the grant. The committee reported last May and commented forcibly on the insufficiency of the funds remaining over for progressive meteorological research. They advised that the service should be attached to one of the great government departments, in which case the present council would not be required. They pointed out how savings to the amount of £2,500 a year might be effected. The National Physical Laboratory had continued its work with success during the year, the last of the five for which the original annual grant of £4,000 was made by the Treasury. A memorandum had been sent to the Treasury which recommended (1) that a sum of nearly £30,000 was required for capital expenditure, and (2) that the annual grant should be raised in the course of four years to £10,000; while, with a view to supporting these proposals, a request was made for an official inquiry into the work and organization of the laboratory. The question was still under consideration. The donations and subscriptions promised to the laboratory, in most cases for five years, had increased and now reached about £2,000. Work had been begun on the new magnetic observatory at Eskdale Muir, for which a sum of £3,000 was provided in the Treasury estimates for the year. Other matters dealt with in the report were publications, the government publication grant of £1,000, and the library. The report also contained the Royal Society's statement on scientific education in schools, made last January, which was forwarded to all the universities in the United Kingdom, and to which many sympathetic replies had been received.

SCIENTIFIC NOTES AND NEWS.

Professor James F. Kemp, head of the Department of Geology of Columbia University, has been elected president of the New York Academy of Sciences.

Professor C. P. Neill, who holds the chair of political economy in the Catholic University of America, has been appointed U. S. commissioner of labor to succeed the Hon. Carroll D. Wright, who will hereafter devote his whole time to the presidency of Clark College. Dr. Wright was given a farewell banquet by the Unitarian Club, at Washington, on the evening of December 14.

Professor Willet M. Hays, who holds the chair of agriculture in the University of Minnesota, has been appointed assistant secretary of agriculture.

At the twelfth annual meeting of the Geological Society of Washington, after listening to a paper by Mr. G. K. Gilbert on 'Crescentic gouges on glaciated surfaces,' the following officers were elected for the ensuing year:

President—G. P. Merrill.

Vice-presidents—Waldemar Lindgren, A. H. Brooks.

Secretaries—G. O. Smith, H. Foster Bain.

Treasurer—M. L. Fuller.

Members of the Council—T. W. Vaughan, David White, F. L. Ransome, M. R. Campbell, T. W. Stanton.

Mr. G. K. Gilbert was selected to represent the society as vice-president of the Washington Academy of Sciences.

Mr. Luther Burbank, the well-known California expert on plant-breeding, has been appointed a special lecturer at Stanford University. It is reported in the daily papers that Mr. Burbank has received a liberal grant from the Carnegie Institution, which will permit him to devote himself to scientific work for the next ten years.

As already announced, the council of the Royal Society of Edinburgh has awarded the Gunning Victoria Jubilee prize for 1900–1904 to Sir James Dewar. In addition, the council has awarded the Keith prize for 1901–1903 to Sir William Turner for his memoir entitled 'A Contribution to the Craniology of the People of Scotland' and for his 'Contributions to the Craniology of the People of the Empire of India,' Parts I., II.; the Makdougall-Brisbane prize for 1902–1904 to Mr. John Dougall, M.A., for his paper on 'An Analytical Theory of the Equilibrium of an Isotropic Elastic Plate'; and the Neill prize for 1901–1904 to Professor J. Graham Kerr, M.A., for his researches on *Lepidosiren paradoxa*.

The Astley Cooper prize of £300, which is offered triennially for medical research on a specified subject, has been awarded to Mr. W. Sampson Handley, Hunterian professor in the Royal College of Surgeons, for an essay entitled 'Epigastric Invasion of the Abdomen in Breast Cancer.'

Assistant Professor Carl Kinsley, of the department of physics of the University of Chicago, will go abroad on the first of January to spend six months in study at the laboratory of Professor J. J. Thomson in Cambridge.

Mr. Chas. T. Kirk, a graduate student in geology at the University of Oklahoma, is conducting some investigations on the subject of concretions. He desires to correspond or to exchange specimens with any one interested in this particular subject.

Professor Hely-Shaw, who has held the chair of engineering for the past twenty years at Liverpool, has accepted the post of principal organizer under the Transvaal Technical Council.

The death is announced of Miss Achsah M. Ely, since 1887 professor of mathematics at Vassar College.

We regret also to record the death of Dr. Karl Ueberhorst, professor of philosophy at the University of Innsbrück.

Several specimens of native gold, some of especial value on account of their crystalline form, have disappeared from the mineral cabinet of one of the leading educational institutions. Collectors and curators of museums are respectfully asked to report to Pinkerton's Detective Agency any information that may lead to the identification of the thief or to the discovery of the whereabouts of the specimens.

It is said that Mr. Andrew Carnegie has given \$540,000 for the establishment in Boston of an institute similar to Cooper Institute, which is to be added to a fund of \$270,000, which has grown from \$5,000 left one hundred years ago by Benjamin Franklin.

The constitutional amendment exempting the California Academy of Sciences from further taxation was carried at the election November 8, 1904, by a majority of nearly 11,000.

The seventh biennial convention of the Society of the Sigma Xi will be held on Thursday evening, December 29, 1904, at eight o'clock in the auditorium of Houston Hall, University of Pennsylvania, Philadelphia.

A western meeting of the American Physical Society is to be held in the Ryerson Physical Laboratory on April 22, 1905. The arrangement of the program is in the hands of Professor Robert A. Millikan, of the department of physics of the University of Chicago.

The Pelé Club will hold its third annual session at Philadelphia, on the evening of December 28. The organization hopes to be of service to the science of geography in collecting and studying phenomena.

We learn from the *British Medical Journal* that a meeting of medical men was held in Paris on November 25, when it was resolved to invite British physicians and surgeons to pay a return visit to Paris. Professor Bouchard, member of the Institut, was elected president of the Paris committee, and the opinion

was expressed that some date early in May—probably between May 7 and 14—would be most convenient.

Negotiations have been completed whereby Purdue University is to receive from the New York, New Haven and Hartford Railroad, through the courtesy of Mr. Samuel Higgins, general manager, the historic locomotive 'Daniel Nason.' A few years ago the university interested itself in securing from railways samples of such classes of locomotives as are now being superseded by machines of more modern construction, its purpose being to preserve as museum exhibits types of design which were in danger of becoming extinct. As a result of this plan, a number of valuable relics are already upon its grounds. From the beginning of this movement, an effort has been made to secure a representative of a type which was common throughout New England thirty years ago, namely, an eight-wheeled engine having cylinders inside the frames connecting with the crank axle. This effort has now been crowned with success. The 'Daniel Nason' is said to have been built in 1858. It was exhibited in Chicago in 1893 and has been held as a relic at Roxbury, Mass. The engine weighs about twenty-five tons, is complete with its tender and will be shipped to the University at Lafayette, Indiana, upon its own wheels. The university is also to become the custodian, in behalf of the same railway, for a stage-coach passenger car which is said to have been placed in service in 1835. It consists of the body of a stage-coach suspended over a simple railway truck by means of thorough-braces. It will seat inside and on its top about twenty persons. The American Locomotive Company has presented to the university the full-sized model locomotive cylinders sectioned to show the piston valve construction, which formed a part of its exhibit at the Louisiana Purchase Exposition, St. Louis.

The lecture arrangements at the Royal Institute, London, include the following: A Christmas course of lectures (experimentally illustrated and adapted to a juvenile auditory) on 'Ancient and Modern Methods of Measuring Time,' by Mr. Henry Cunynghame; Professor L. C. Miall, Fullerian professor of physiology, R. I., six lectures on 'Adaptation and History in the Structure and Life of Animals'; Professor Karl Pearson, three lectures on 'Some Recent Biometric Studies'; Professor W. E. Dalby, two lectures on 'Engineering'; Mr. A. H. Savage Landor, two lectures on 'Exploration in the Philippines'; Professor W. Schlich, two lectures on 'Forestry in the British Empire'; Mr. J. J. H. Teall, two lectures on 'Recent Work of the Geological Survey'; Professor H. H. Turner, three lectures on 'Recent Astronomical Progress'; Professor R. Meldola, two lectures on 'Synthetic Chemistry'; Professor J. J. Thomson, three lectures on 'Electrical Properties of Radioactive Substances'; and Lord Rayleigh, three lectures on 'Some Controverted Questions of Optics.' The Friday evening meetings will begin on January 20, when a discourse will be delivered by Professor Sir James Dewar on 'New Low Temperature Phenomena'; succeeding discourses will probably be given by Dr. E. A. Wilson, Mr. Cecil Smith, Mr. J. W. Gordon, Professor H. Marshall Ward, Chevalier G. Marconi, Professor J. J. Thomson, Sir Squire Bancroft, Professor G. H. Bryan, Professor J. Wright, Professor T. Clifford Allbutt, Lord Rayleigh and others.

UNIVERSITY AND EDUCATIONAL NEWS.

The regents of the University of Nebraska have passed a resolution accepting a gift of $66,000 from Mr. John D. Rockefeller for the erection of a building to be used for religious purposes.

Dr. Fowler, late president of Corpus College, Oxford, has under his will left £1,500 to his own college, a like sum to Lincoln, of which he was formerly fellow and tutor and honorary fellow at the time of his death, and £1,000 to Merton, where he was a post-master.

Mr. Clifton D. Howe, assistant in the department of botany of the University of Chicago, has received an appointment to an instructorship in botany in the Biltmore Forestry School.